TEXT FLY WITHIN THE BOOK ONLY

THE BOOK OF THE MICROSCOPE

THE BOOK
OF
THE MICROSCOPE

BY

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AUTHOR OF

"THE ROMANCE OF THE HEAVENS"

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FOREWORD

THE USE of the microscope in schools on a more extended scale has secured an interest in this fascinating pursuit which did not obtain a few years back.

This is a book primarily for the beginner or the student who has begun at school, has dropped microscopy, and now wishes to take it up once more. The aim throughout has been to foster interest and to show how the more simple apparatus may be made the most use of.

The telescope is a first cousin of the microscope, and the two kinds of apparatus are now frequently possessed and used in conjunction. Chapters dealing with the telescope in its more interesting aspects are therefore included here.

The following authorities have been consulted: The *Encyclopædia Britannica*, "How to Use the Microscope" (Rev. A. Hall), *A Popular Handbook to the Microscope* (Lewis Wright), *Ponds and Rock Pools* (Henry Scherren, F.Z.S.).

The author is especially grateful to the Director of the Mount Wilson Observatory, California, for

permission to include an account of the remarkable work accomplished there.

The author also wishes to thank Messrs. F. Davidson and Co., 143–149 Great Portland Street, who kindly supplied all the photo-micrographic illustrations.

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THE BOOK OF THE MICROSCOPE

CHAPTER I

THE SIMPLE MICROSCOPE

THE average person confronted with the word microscope will probably say, "Surely this is rather a dull subject, and I do not think that it will interest me particularly." Time was perhaps when this might have been true, but the vast interest which has been built up through the use of the microscope during the past half century, coupled with the improved and cheapened apparatus available, has made the pursuit of microscopy one of the most fascinating which it is possible to suggest to any-one in search of a pastime which has practically no limits.

To take for a moment at the outset some of the fields in which the microscope can be employed. First of all, there is the closer study of botany; the watching of the beginnings of life in all its forms; the analysis of the contents of a pond; the exploration of the seashore, and particularly of the rock pools found there; the fascination of the insect world, when put under the magnifying glass, and

then the geological specimens which can be brought for easy examination.

It is not pretended that the above list by any means exhausts the whole of the subjects which can be brought to the microscope; indeed, as one goes on, the difficulty is to know where to stop. Observation, however keenly it may have been developed, is developed even farther, and a country walk, with all its present joys, has additional interests added by the possession of even the simplest of microscopes.

Without any exaggeration it may be claimed that the possession of a microscope adds a completely new interest to life, and enables many beautiful and wonderful objects to be studied at leisure, when, in the ordinary way, they would have been passed or voted as not worth while. To anyone regularly using even a pocket magnifying glass, it comes as a surprise to know that the vast majority of people have never bothered to carry even one of the cheapest kind. On the other hand, many observant people have been tempted to invest, first in a simple magnifying glass, and then, encouraged by the results which they have obtained by its use, have launched out into the expenditure of quite considerable sums, to obtain a microscope which was really worth while.

It is one of the disadvantages of many of our words that they suggest hard work, or some study, and this is very true of the word microscope. The average boy, for instance, will probably be quite willing to hear something about a magnifying glass, but if you mention to him the microscope, and the

study which comes through its use, he will be inclined to shy, and make some excuse for not becoming even a little interested. Fortunately, however, the present tendency is for greater interest to be taken in all sciences, and it is especially true of what we may call the popular sciences. We shall not be far wrong if we include microscopy in the popular sciences, even if by using the word "science" we rather suggest something which is not all pleasure.

Quite easily a new-comer to the microscope may ask to be told something about it, how it got its name, and for what main purpose it is used. The term is derived from the Greek words *Mikros*, meaning little, and *skopein*, meaning to look at; so that if the word is at all forbidding, let us put it down to its Greek origin! It is an undoubted fact that words with Greek origins are usually more formidable than those derived from the Latin tongue. Thus, a good definition of the microscope, apart from that given above, might be that it is something which will present to the human eye an enlargement of the object examined. Wonderful and powerful as is the human eye, we are well aware that it does not take in the more minute organisms of many objects. A water bottle, standing upon a white tablecloth, will present a microscope in a very effective manner, for, looking through the water, we observe at once that the texture of the linen tablecloth becomes very much like coarse canvas. The water bottle, then, is doing for the eye what the lens can do so much better, because it is more readily adaptable to any object which it is desired to examine.

The simplest form of microscope is just an ordinary magnifying glass, sometimes of the folding variety, which can be easily carried in the pocket, but very often with the fixed handle, such as is used for reading. The compound microscope is, as its name suggests, an instrument with at least two distinct lens systems, these are called the eye-piece and the objective respectively. The best example of a compound microscope which comes to mind is a telescope, where we have the objective glass at one end, and the eye-piece at the other. But a telescope, simple as it may appear, is not suitable for focusing upon any object close at hand, and thus the idea has been carried farther, and we have the modern microscope, which may be quite a simply made instrument, or, on the other hand, very elaborate. The object to be studied is placed under the objective and then focused by it. This reproduces a magnified image at a certain distance behind it, which is further magnified by the eye-piece. How far the magnification can proceed depends upon three details; first by the power of the objective, second by the power of the eye-piece, and third (in low power microscopy only) by the length of the tube employed.

Before proceeding farther with the study of the microscope in its various forms, let us suggest that a beginner makes his own microscope, and that it shall be of the simplest form possible. We may suggest that the novice will actually begin to be interested in the microscope by the purchase of a fairly powerful magnifying glass, which folds up to

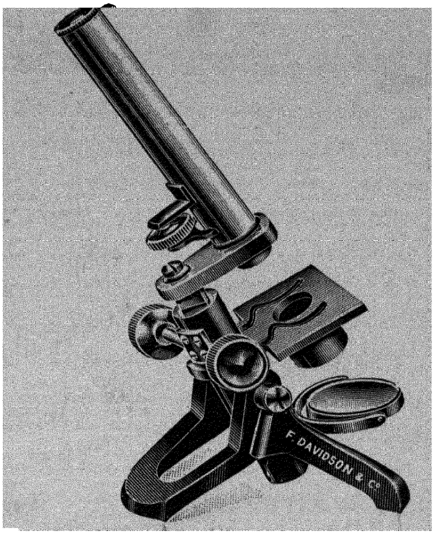
be carried in the pocket or handbag. This is a very handy form of microscope really, and even when the next step is taken, and the microscope is made or bought for use at home, the magnifying glass should always be carried, as it will enable the objects to be examined on a country ramble, and by it may be determined whether they are worth taking home or not.

A first rule for a rambler in search of objects, is not to bother too much about carrying along anything which can be seen quite comfortably with the naked eye; reserve your efforts for the things that matter, and these, as a rule, must be placed under the microscope. The preliminary examination can be done *en route*, and then the objects, of whatever class they may be, are transferred to some suitable receptacle to be carried safely home; be careful, of course, not to mix them, otherwise it will be difficult indeed to say which is which. A good plan, and having the advantage of simplicity, is to take out a tin box which can be carried conveniently in the pocket or handbag, and a series of small boxes, also of tin, if possible, which may be packed inside, each of them containing a different object. Boxes which have been used for gramophone needles take up little space, and will be found very efficient for carrying in the larger box. Lozenges are usually sold in tin boxes, and these should be saved for use with the microscope.

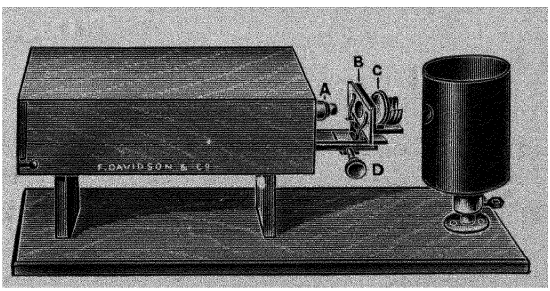
We need not indicate here the objects for which the novice should search, that will come in its place. Let us rather see how the simplest form of microscope

can be built at home, upon which the first experiments will be carried out. The great advantage of making a simple microscope of one's own, is that if the pastime of microscopy does not really appeal after having been given a good trial, there is little loss entailed. It is quite a mistake, unless you are sure that you are going to be keenly interested in the microscope, to purchase anything of an elaborate nature in the way of apparatus. The best microscopes are not cheap, and although it is an excellent plan to go to a reliable second-hand establishment to secure your microscope, it is far better to begin with the one we are about to describe.

The design of this microscope is really to use on a stand a folding magnifying glass; indeed, the actual glass which is carried in the pocket may be used upon the stand if desired, and this would appeal to those whose pocket-money is strictly limited. On the other hand, it is a good plan, if funds permit, to buy a good, powerful folding glass for use with the home-made microscope, and keep it permanently on the stand. Assuming the glass to be available, the next step is to purchase a piece of good timber which must be well planed, practically any kind will do, but if a cabinet-maker's shop is in the vicinity, the chances are that an oddment well worth having can be obtained for a copper or two. There may be a spare piece of mahogany, oak, or teak, lying by, even pitch-pine will serve the purpose, and, as a last resource, common deal may be used. But it is desirable to have something which will not only be of use, but not look too amateurish when completed.



A SIMPLE FORM OF MICROSCOPE



A SIMPLE PHOTO-MICROGRAPHIC OUTFIT
With which the most excellent results may be easily attained.

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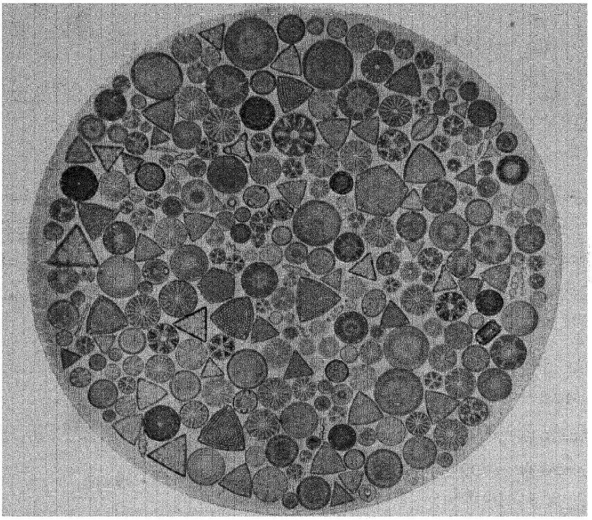
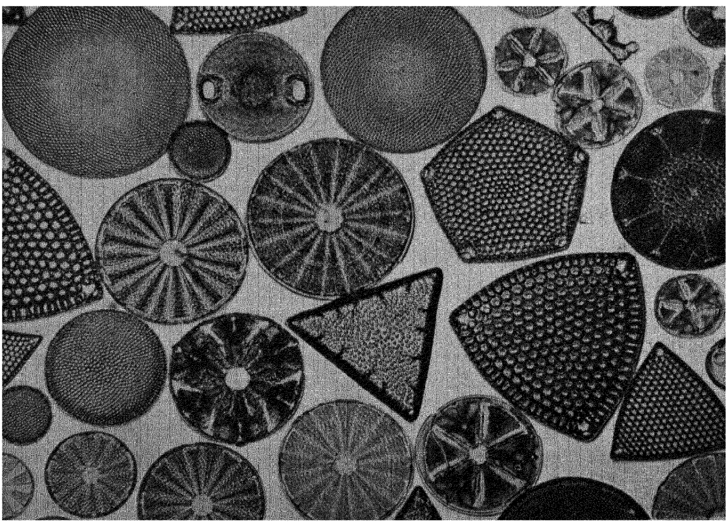


A Group of Diatoms × 50



Another Group of Diatoms
Showing the many and beautiful shapes they assume.

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The piece of timber is required for the base of the microscope, and the thicker it is, up to say one and a half inches, the firmer will be the stand, and the more successful your experiment; avoid, in any case, having a top-heavy instrument. Having obtained the base of your instrument, the next step is to purchase a sliding penholder or pencil; these are probably not so easily obtained now as formerly, because the cheap fountain pen has largely ousted the sliding penholder, but they are obtainable, and the best one that can be purchased is essentially well worth while taking home. The object of the sliding penholder will be apparent; it is that the upper portion may move up and down inside the lower, in order to focus the magnifying glass. The next step is to fix the magnifying glass upon the top of the sliding penholder, which by the way, must be firmly secured into the base of your instrument. A gramophone needle is usually available, and this makes an excellent point for the handle of the folding magnifying glass.

The vulcanite handle of the magnifying glass will have to have a small hole bored through it to take the point of the gramophone needle as the existing hole will probably not be large enough, great care must be taken not to split the handle by too vigorous boring.

The next step is to provide a second base upon which the objects to be magnified can be placed; this, it will be observed, comes rather more than half way up the barrel of the pencil holder. This base may be made from three-ply wood, or even stiff cardboard, but the best material is undoubtedly

the kind of black vulcanite or ebonite which is used so largely nowadays with wireless sets. A sheet of vulcanite, or whatever material is used, must be rather smaller than the base of the microscope, and it will be necessary to cut out a small portion in order that it may be fitted to the barrel of the upright. Perhaps the easiest way to fix it is to have a hole drilled through the sheet so that it encircles completely the barrel of the microscope's support. Some little difficulty may be found in fitting this sheet, but it will be the only trouble experienced in building the home-made apparatus.

In order to bring the objects on to the focusing table, which the ebonite sheet has now become, it is an excellent plan to use either discarded lantern slides, or old photographic plates from which the film has been cleaned off. It is much better to have these loose plates than to place the objects directly on the focusing table, and in this manner it will always be kept quite clean; in addition, it is frequently necessary to affix the objects to be examined with some adhesive substance, and there is nothing better than glass for this purpose; therefore the number of glass slides available should be as large as possible. Boxes should be made or adapted in which the slides, with their objects upon them, can be stored. If partitions are placed within the storage boxes, it will be found that the objects can be brought out from time to time, for your own amusement and that of your friends.

We have here then the beginning of microscopy, and the simplest form of apparatus provided for the

first attempts to a most fascinating hobby. Although not absolutely necessary at this stage, there are certain small instruments which can be purchased quite cheaply for use with the home-made microscope, and these will enable your work to be done better, which means, in turn, that it will be of greater interest.

Amongst the first of these items to be obtained are the various kinds of forceps; they are very useful little articles, and with them it is possible to turn your objects in any direction without the slightest trouble. Even the most delicate fingers are inclined to be rather clumsy when dealing with very minute objects, or again, when the objects are very thin, such as the edge of a leaf, or a wafer of some substance which it is desired to examine closely. Scissors are an important factor in preparing objects for the microscope, and it is as well to have two pairs reserved entirely for use with your apparatus; one of them should be of the strong and straight variety, but the other pair should have curved blades, and be fashioned altogether upon more delicate lines.

You will need a variety of needles, varying from the bodkin kind to those of the smallest diameter possible. For use with the microscope it is possible to buy them specially prepared, and some of them it will be found, if bought in a packet, are curved. It is, however, not absolutely necessary to buy your needles, as anyone at all clever with their hands may take the ordinary kind of sewing needles and push them into close-grained sticks; three-fourths of the needles should be sunk in the stick, and it will then be found

possible to bend them into the desired curves. It will be found that the ordinary needles are very brittle, and perhaps it would be as well to test them to see if they may be brought to white heat and then bent. On the whole we should suggest buying the needles, and also the holders, which are sold specially for use with the microscope.

As it will be necessary to obtain dipping-tubes, it will be just as well to purchase the needles at the same time. Again, if the beginner in microscopy is anxious to do as much as possible towards providing his apparatus, the dipping-tubes may be home-made too. All that is necessary are several lengths of thin glass tubing; these have to be heated until it is possible to manipulate them, and they can then be drawn out to any shape desired. Be careful, on doing this, not to seal up the ends of the tubes by allowing the glass to become too molten. Some experimenters with glass tubes say that they are very much easier to manipulate than the usual type of glass syringe, as liquid may be sucked up quite easily, and then be transferred from one bottle or bowl to another, simply by placing a finger over the wide end, and then allowing the tube to fill with liquid, by removing the finger, afterwards reclosing it in a similar manner. To expel the liquid remove the finger. Really the same principle is involved as with the old-fashioned fountain-pen filler, indeed, if desired these fillers can be used in place of the method indicated above.

Another useful adjunct for the simple microscope, and indeed for the compound apparatus, is a watch-

glass; better still, a series of them of varying sizes can be purchased. They are quite cheap, and they are extremely useful for containing objects of a fluid nature. The watch-glass will not, however, do for anything which has a considerable amount of fluid, or is of any real size; for these, the small, shallow salt cellars, porcelain ointment boxes, and particularly the smaller porcelain photographic developing dishes are suitable.

Another accessory for work with the microscope is a scalpel; this is a very useful instrument, but it is not absolutely essential, because all the work that can be done with a scalpel can be done almost as well by a really sharp pocket-knife. It is necessary to point out that whatever is bought for use with the microscope, such as scissors, etc., must be of the best quality; they are going to be put to do intricate work, and therefore they must not only be well made to begin with, but they must be kept in very good trim; cleanliness is as essential in microscopy as in other delicate work, and on no account should anything which is used be put away in a dirty state. Scissors and scalpels will be used for dissecting various objects, and unless cleaned and oiled when put away, it will be found that they will have become almost useless for the next time they are required.

Do not let this rather formidable list appal you; if you know anything about any hobby, you will know that it cannot be followed without proper tools, these are the minimum tools for use with the home-made microscope. You may save yourself considerable trouble by going to a reputable firm, and

asking whether they have a cabinet with the tools mentioned, preferably second-hand, which they can offer you. It is, however, possible to buy one new for ten shillings and sixpence, and if the microscope described here has been made at home, it will be found that your total outlay for a start in microscopy is well under one guinea. It is certain, however, that once you have started thoroughly with this modest beginning, you will want to go on still further, and make it a pastime which may continue throughout your life.

It will never pall, and it has this advantage over many other hobbies, that it can be put aside and picked up at any moment, therefore, wherever you go, and into whatever country you may travel, you will find that there are objects at hand, many of them new to you, which will be a constant source of interest.

CHAPTER II

TYPES OF MICROSCOPES

BEFORE the microscopist can begin work in earnest it is necessary that he or she should know something of parts of the instrument with which he is to work. We have already seen how the simplest form of microscope is made at home, and here we assume that the beginner, having got so far, will want to go ahead. Mention was made of the hand-glass which all should carry whether they possess a microscope for home use or not. But there are many kinds of pocket glasses, ranging from one which costs just a copper or two, to the more elaborate affair which possesses several lenses. A very useful type is that with the triple lens, and it has the merit of being quite cheap—a matter of five shillings being about the price for a very useful pocket magnifier.

The double-lens instrument costs less still, but it is well worth while purchasing the instrument with the extra lens.

Still more elaborate, yet well worth while possessing as an adjunct to the microscope, is the Pocket Aplanatic lens, which really consists of three lenses cemented together. The price of such instruments range according to such points as magnification, working distance, and visual field. These glasses

are especially suitable when it is desired to dissect objects for examination.

These, then, are examples of useful pocket apparatus which any good optician will either stock or obtain.

The compound microscope is usually the next step for the beginner who has mastered and enjoyed the use of the simple type. At once he has a vast new field opened to him. Nor need he spend a tremendous amount of money on his instrument. There is a somewhat prevalent opinion that microscopy is an expensive hobby; actually it is one of the cheapest possible when once the first expense has been met. The apparatus of all descriptions is practically everlasting, and it is only when one is urged to go from strength to strength, as it were, that there is any approach to extravagance. In addition, it must be remembered that all apparatus purchased, if treated with ordinary care, has a distinct second-hand value.

We are so accustomed to think of second-hand values in connection with motor cars and push cycles, where an enormous proportion of the first cost must be written off, in most cases, after a few months' wear and tear, that it is refreshing to find that the microscope certainly does not come into this category. Providing the apparatus is really good to begin with, its value does not seriously decline with age, though, of course, one has to remember that here, as elsewhere, the note is ever of progress. Yet, again, this helps the beginner decidedly because the confirmed and enthusiastic microscopist, in his desire to be right in the forefront of progress, will often offer for sale, generally through the medium of such a paper

as *The Exchange and Mart*, his apparatus, which, though not by any means obsolete in any sense of the word, is so considered by the enthusiast, who not only wishes to have the latest apparatus with the greatest number of refinements, but also has the necessary means to purchase the new, offering the old at such tempting prices that the new-comer to the hobby finds himself in luck's way.

It is, therefore, very good advice to give when we say "Buy second-hand when you can, but be sure that you are getting good material." And here we should specially stress that the advice of an experienced microscopist will be well worth while seeking when a purchase is in view. In most cases the novice will have become interested in the hobby by meeting some enthusiast, and most probably will have begun work under his direction. That is the man to help you to the best apparatus. You will profit by any mistakes he may have made, and he will be able to advise on what you ought to pay, what you ought to get, and what its condition should be.

It is necessary here to stress that Britain has long been the home of the best products in this direction. It is quite true that the Germans—and to a lesser degree the Americans, have become great rivals, and have produced excellent microscopes of all kinds, but the British manufacturer has always kept in the van of progress, and the slogan "Buy British" is not only patriotic advice to give, but it is essentially good advice.

Some years ago, for some reason not quite clear, though possibly because the agents got a bigger

profit, the German apparatus was pushed forward, particularly in schools and colleges. The result might be foreseen; it led to a few of the well-known British houses, either going out of business or switching over to some other service. Both London and Manchester have some opticians whose apparatus is absolutely reliable, whose prices are not dear, and whose lists contain a sufficiently wide range of microscopes to satisfy every need.

Half a century ago really good microscopes were quite beyond the purse of the average man, and impossible for the boy even at second-hand prices, but such great advances have been made in lens making that good apparatus has come down considerably in price, even allowing for the increased cost of everything due to the War, so that even compound microscopes are within the reach of most people. More particularly the lenses have improved beyond all predictions of the microscopists of the 'eighties and 'nineties of the last century. A good deal of this improvement is directly due to the competition of German makers who have made an especial study of lens making, and, with the thoroughness for which that nation is noted, have produced really remarkably fine glasses. This has had the effect of stimulating British manufacturers, some of whom have not disdained to use German lenses for British-built stands. Stands, too, have greatly improved, showing markedly better results when the objects are placed in position. The finer adjustment is especially valuable.

It is good advice to give to a purchaser of a new

or second-hand microscope to say that the adjustments should be very carefully examined. There are sometimes quite good lenses fitted in stands which scarcely deserve the name. If the apparatus is well designed and well built it should be possible to vary the fine adjustment by the merest touch of the finger. The coarse adjustment should work easily by rack and pinion. If this is hard in a new instrument the shopman will often say, "It is bound to be stiff now, but it will work easily when you have had it a little time." Beware of this. The shopman may believe that this is indeed the case, but the expert microscopist would say otherwise, and that it should be, at the outset, perfectly free-working before the apparatus leaves the workshop. Beware also of signs of abundant grease, either with new or second-hand apparatus. The new should not have grease at all, whilst obviously, if the shopman is right about apparatus working easily after being in use for a short time, the second-hand microscope should not need oil or grease.

Another good piece of advice which has been given by an experienced microscopist is that, if funds are not too flush, a good second-hand piece of apparatus should be obtained which should be capable of having what we might term the refinements added later on, one by one, as funds permit. The apparatus in mind should have one eye-piece, two good objectives and, most particularly, a really good stand. One possessing a focusing and centring substage would be an advantage for high power work later on.

We may now take a look at the kind of microscope which you should make up your mind to possess—one that will give all the results which you are likely to want to obtain—for a year or two at anyrate—even if ambitious; such a microscope, in fact, which will serve the average person for his lifetime.

Begin then with the foot. This should be of massive construction and very firm on its base, so that when the microscope is used, even in the horizontal position, it should not be apt to topple over, and when in the vertical or at an oblique angle should be quite rigid.

Next comes the stage to support the slide, or the object upon which you wish to concentrate your attention. The stage must have a small aperture bored in its centre in order that illumination may be obtained from beneath; the aperture varies in size with different stages, but it should not be less than an inch across.

The best stages are fitted with a sliding attachment known as a "mechanical stage" which enables one slowly to move the object under examination in both the horizontal and vertical planes, and is especially useful in examining objects in a systematic manner and is essential when one advances to high power magnification. A refinement which is sometimes added, and often stipulated by experts who need the microscope in their profession, is a circular rotating stage. This need not be asked for by the amateur; it is particularly needed by the person who has to use his instrument for the examination

of various minerals. It is mentioned here as, assuming that a second hand microscope is being bought, the prospective purchaser might wonder what the respective advantages and disadvantages of the rotating circular stage might be.

Then we come to the tube, called the Body Tube of the microscope, which not only carries but connects the lenses. There is no standard length, and usually a variation of between six and a half and ten inches will be found. If you asked an expert which length to choose he would probably pause before giving his reply as there has been a considerable amount of controversy upon this point. In the cheaper instruments six and a half inches is usual, whilst eight and a half is preferred by a number of people; on the other hand there are quite a large number of tubes on sale of ten inches, most of them originating abroad. The best arrangement, of course, is to have a sliding draw tube and if one intends to do high-power work later on this is absolutely essential. If a second-hand instrument is sought for this is a point to be watched.

All tubes should have what is called a "society" screw placed at the bottom, and it is well worth noting that, although general practice in the make-up of an instrument differs between country and country, and between maker and maker, the "society" screw and its arrangement is practically standard throughout the world. Its use is to allow of the objectives being placed in this position. At the other end of the tube comes the eye-piece, which you should note is easily removable and should

fit in quite easily without being forced in any way. At the side, and usually at the point of the tube nearest the microscopist, comes another fairly large screw; this is known as the coarse adjustment. This is operated by rack work, which should work easily to enable an accurate focus to be obtained. In the cheapest kind of apparatus the screw and rack-work is superseded by a sliding arrangement, but this is hardly ever satisfactory.

Next comes the fine adjustment, which may be placed in various positions. Here again the best action is obtained by the movement of a carefully-adjusted screw.

The mirror is of great importance, and, wherever possible, it is desirable that it should be fairly large. The mirror will be found flat on one side with the other concave in shape.

Lenses need care if bought separately from a good microscope. It is, however, frequently desirable to add to the objectives supplied with a stand. The best advice which can be given in this connection is either to go to a reputable agent, or to get the services of a friend who is well up in microscopy.

Four of the best known German makes are the Zeiss—known the world over—the Seibert, Reichert and the Leitz. Of the British makes those turned out by Watson, Swift & Beck, are excellent, and, if money is not too tight, it is advised that home industry should have the support of the new-comer to microscopy.

For general microscopic supplies the firm of C. Baker, of London, has a high reputation, and

they are particularly interested in the kind of apparatus which a novice would require.

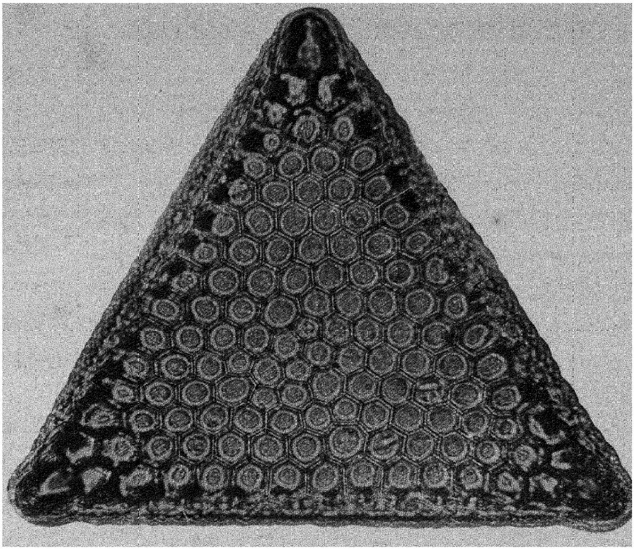
There are just a few words to be said about objectives and their qualifications. The first thing to look for in a lens is its power of definition. If it shows a rather blurred line be careful and make test after test to find out whether the fault is with the objective or elsewhere. The line of the image, if it is already quite fine and clear-cut, should be especially so through the glass. In many cases the first fault found with a cheap foreign lens is this lack of definition. A good deal depends upon the eye-piece used with it, and none but an expert would definitely throw out a lens on a first trial, and only a few experts would be content with a single trial, because a good deal depends upon the eye-piece, and also upon manipulation. Again, a cheap lens will do wonders if allied to a suitable eye-piece.

These are general hints for the beginner, and it is not intended here to enter into the intricacies of microscopy; were we to do so it is conceivable that we might frighten off the aspirant, and then all would have been written in vain.

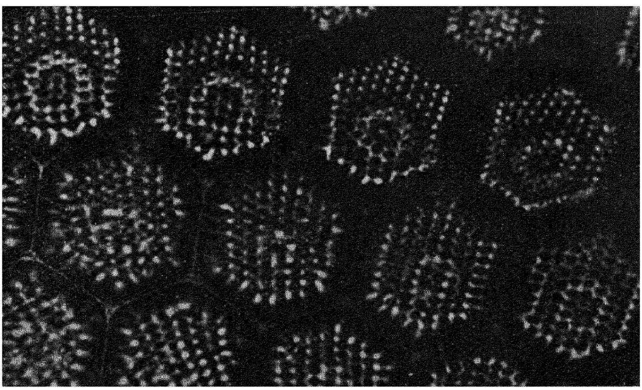
The great point in all hobbies is that they shall be as simple as possible at the beginning, and then, if they appeal, the novice will want to go farther. To enable him to do this there are many excellent and quite cheap books. Although it may be desirable, and well worth while, to buy the latest and most up-to-date treatises, it is remarkable how many really excellent volumes will be found on the shelves

of a second-hand bookseller, any of which may be bought for less than a couple of shillings.

The subject is such a vast and interesting one that handy little volumes are constantly appearing which will open up new vistas for the keen microscopist. One very great point to remember in searching the shelves of the second-hand bookseller is to avoid the oldest volumes. It is not that they are inaccurate, rather that they take one only a little distance in the quest for knowledge; more particularly, all the good things in the old books must necessarily have been included in the new. Apart from this, there have been such wonderful advances in apparatus, that many experiments and objects which were not considered possible fifty years ago, are now within the range of the merest amateur with a reasonably good instrument.



DIATOM TRICERATUM FAVUS



DIATOM TRICERATUM FAVUS
This shows detail of the above diatom.

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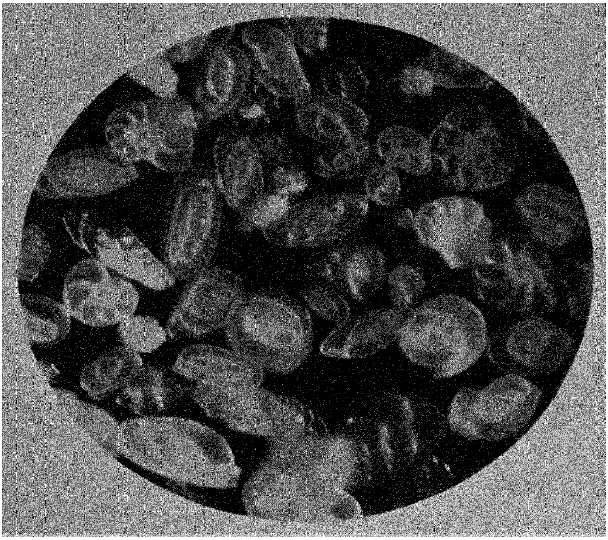
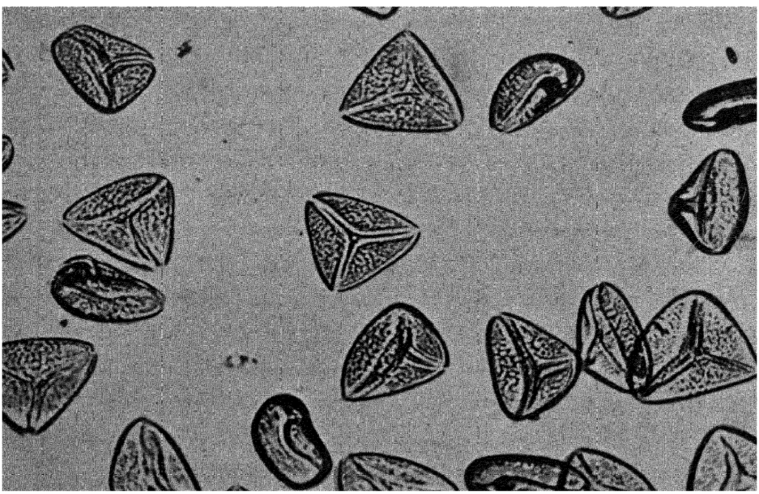


FORAMANIFERA
This shows clearly the shell formation of chalk.



STRUCTURE OF THE POLLEN OF NEW ZEALAND FLAX
Note the pyramidical shape.

Face page 23]

CHAPTER III

HINTS ON THE MICROSCOPE

ONCE a microscope is in the possession of the novice he wants to get straightway to work. But there are a few very necessary hints that are well worth having as they will help considerably to get the best out of what is often rather a complicated piece of machinery.

It has been well said that the first important lesson for the microscopist to learn, and always remember, is the care of his eyes. Just as a keen reader will often do irreparable injury to his eyes through following too closely his favourite recreation, so, too, may the enthusiastic user of the magnifying lens do harm. Whilst the reader is using both eyes upon fairly large print, the microscopist is following with one some of the tiniest objects imaginable—even when magnified.

Some users of the microscope will not work in the best light possible, whilst others will always persist in screwing one eye up when using the other. Use both eyes—in turn—and when you feel the least strain, however interesting your work may prove, give your eyes a rest. They are your best friends with the microscope—always remember that they are one of your chief assets away from it. In

striving for a good artificial light to comply with the advice given above, do not go to the opposite extreme and work in a trying glare. There are many ways of toning down the artificial light so that whilst sufficient for your purpose, no harm results; these will be noted in due course.

All expert microscopists advise the training of the eyes so that whilst both are kept open, only one is really used; and this is far better than shutting one. It may be added that this is not easy at first, but the result may be easily achieved by practice, just as the telephonist in training is taught to listen with only one ear, which explains why she can do her difficult work in an Exchange where hundreds of girls may be speaking.

If real difficulty is at first found in using one eye with the other still open, try a home-made gadget which is, in effect, a dark screen for whichever eye is not being used. It consists of some wire bent to form two rings at either end, the centre connecting piece being perfectly straight, not bent to fit over the nose. The two rings are so arranged that they will cover both eyes. Whilst one is left clear and affixed to the eye-piece of the microscope, the other is covered with any dark substance available. A piece of carbon paper will do admirably, though it is not very lasting. Possibly a piece of black linen binding would suffice and prove very durable.

Another hint is to watch your illumination; this not only means lessened eye strain, but the easy observation of much that will be lost, inevitably if illumination is defective. It is quite useless having

splendid lenses and most accurate focusing if the illumination is all wrong.

Every beginner makes the cardinal mistake of trying to magnify as much as possible; it is quite a natural tendency, but, unfortunately, it is quite wrong. There is a proper stage in the magnification of an object; to go beyond it means something very much like distortion. It is, of course, very true that between three observers there will be a vast difference in the strength of their respective eyes, and what one will see with ease will be far from being the case with another. How then can a beginner proceed on safe lines? The best advice here is to begin with the one-inch scale and work with that until you are certain that you may go to the half-inch, and then on to the quarter-inch. Quite a number of novices begin with the quarter-inch, and think that they are taking the best course by using it at every possible opportunity.

One expert microscopist goes so far as to advise that, except for what may be termed special studies, the amateur should never use less than the half-inch scale, and he lays it down that, as a general rule, those who use the microscope merely for amusement and general objects, the half-inch and inch scales will be found quite sufficient. Summing up, it would seem to be the best plan to adapt your scale to your particular needs, bearing in mind what advice has been given above. Again, if you have a comparatively large object you may have to employ a lower power to get as much of it in the field of vision as possible.

Another item worth emphasising is that if you are to get the best use out of your instrument, you must train the eyes to work carefully upon the object. Some time ago a youthful microscopist was on the point of selling his instrument after having it for a few months. When asked the reason he said, "Well, as far as I can see, one can do quite as well with a hand-magnifying glass, and I can't be bothered with all the gadgets I'm told I must use to get the best results." Fortunately, this was said to a friend, who had himself not long before become acquainted with the wonders disclosed by the microscope. The younger fellow was asked to come round and see the instrument of the older microscopist, bringing his own. They spent a pleasant evening together, at the end of which the youngster had gone home rejoicing with the words, "I see now that I've got to educate my eyes. I've been seeing without seeing!"

And this may be quite true of many new-comers to microscopy. It is not enough to put an object under the glass, examine it casually, and then pass on to another. You must get everything possible out of each object placed on slide or stage, and only by patient experiment will you do so. But once you have accustomed yourself to this procedure, you will find a new interest, and so will microscopy become a hobby really worth while, quite apart from its educative side, which cannot be too much stressed.

It is good advice to give to any who are contemplating the purchase of apparatus to say, "Do not

spend your money on it unless you have patience and leisure." But in saying this let us be clear what leisure really is. The men who have the most leisure are the busiest of all. That may seem rather a tall statement, but it can be proved in quite a simple way. Pick out from your list of friends any one of them who appears to be an exceptionally busy fellow, and ask him what he does with his time. In nine cases out of ten you will find that he so allots it that he fills every waking hour, and that he has quite a number of hours each day to devote to favourite pursuits.

Quite recently the writer came across a busy professional man whose practice took up eight hours of the day; he found time to write books, to paint pictures, to entertain his friends, to devote himself adequately to his family, and yet have time for other pursuits, including sport. Asked how he managed it all, he said, "I make up my mind each day when shaving how it is to be spent; not always can I follow my allotment, but I do contrive to fasten first upon the things which matter, and then I can devote what remains to those which interest me, but are not essential to be done at any particular time or day."

That advice seems so sound that it is passed on, because it is hoped that no one will climb half the hill to the goal of the good microscopist—efficiency—merely to roll down again without having thought the whole climb worth while.

Now to the care of your apparatus, assuming that you have the set which is going to give you hours

of real pleasure. It is a strange fact that the man who will spend hours looking over and cleaning his car, his gun, or his sailing or motor boat, will often neglect more delicate machinery or apparatus. Boys, too, will look carefully over their cycle—motor or push—but will not think that the microscope calls for any attention beyond a casual dusting over. But, for good results, we have seen that good apparatus is essential; it is still more essential that such apparatus must be kept in tip-top condition.

Here is how it may be done—just a few hints easy to follow. Dust frequently, but gently, using a very soft velvet, or, better still, a chamois-leather duster. If the instrument is easily packed away, and not too frequently needed, it is an excellent plan to keep it in its case. But this cautionary measure has certain disadvantages, especially to the busy fellow. He will say, "Oh, I think I would like to have a go with the microscope to-night—I've got an hour to spare." Then he pauses and remembers that the instrument is in pieces and packed neatly in its case, and that the case is placed out of harm's way—so nothing is done, and by degrees the fascination of the hobby is lost, the instrument really valueless. Far better to buy a glass case, such as is made specially for such delicate instruments as these, and keep the microscope ready for action on a side table. These cases can be bought new or second-hand at most opticians, whilst the really handy fellow may make one quite easily. If you have the tools to make a picture frame, you have them already for the putting together of a very satisfactory dustless case.

It is a good plan to have a stand, of a fairly good weight, covered with velvet or similar material. The same material should be used for a surround for the bottom framing of the case; this should make a dustless joint. Despite all this care the apparatus is bound to pick up a certain amount of dust, and it must therefore receive attention from time to time. Many people dust vigorously; this will not do with the microscope, and the work should be accomplished with the greatest care; especially should the dusting be done with some material that will not throw off fluff of any kind. Nothing beats a really good piece of wash-leather, though there are some close-woven materials that may be even better, such as are sold for polishing for instance.

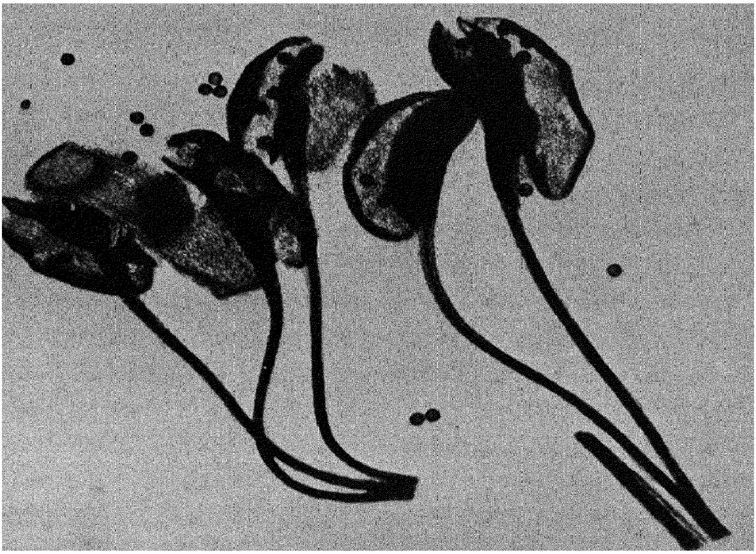
Although it has been stressed that oil should not be used on any part of the instrument, it may be desirable, especially with apparatus operated infrequently, to use the smallest amount of vaseline possible for screws, etc. Try not to give too much, for vaseline is, naturally, a collector of dust.

When going over apparatus the microscopist may observe—or rather become aware—of something being loose which should not be so. It may be quite a simple matter, but it is well not to interfere with the delicate adjustments until you are thoroughly acquainted with their uses and their method of tightening or loosening. Get a friend to advise you; failing a friend, it is well to take the instrument to an expert. He will charge only a small fee, and quite easily a mistake on your part may need the provision of a new section running to five times the

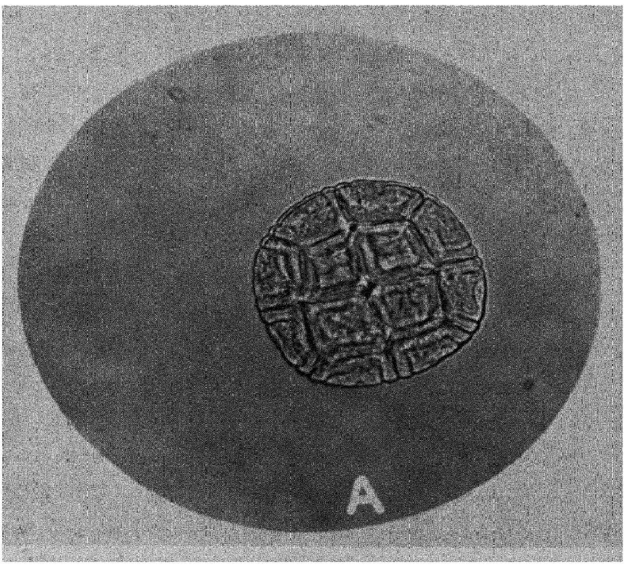
cost of the adjustment which the expert would make. When you are quite familiar with the working of the apparatus it will be rare, indeed, that you need trouble anyone in this respect.

A special word of caution is necessary to the beginner with regard to the lenses, or, indeed, any of the glass surfaces found with the microscope. If you are compelled to wear spectacles or eye-glasses you may often have been puzzled at the filmy appearance of the glasses. You will think, most probably, that you have never polished them with anything that could give them the slightest approach to greasiness, and yet we most of us know that the polishing of the glasses must be done very frequently if they are to do their work.

Actually it is the handling of them in most cases which adds the film. Not only does it come from the fingers, but too often from the breath. It will, therefore, be clear that too much care cannot be taken in dealing with the objectives of the microscope. An oft-repeated piece of advice, given in practically every book on the microscope—and stressed here again—is to avoid touching any of the glass surfaces with the fingers; avoid, too, breathing upon it. Some people clean their spectacles by alternately breathing upon them and then polishing. This won't do with the lens of the microscope, simple as it seems. It will frequently happen that dampness will lead to condensation. The remedy for this is to keep the apparatus in as uniform a temperature as possible; if, in spite of this, there is condensation, get rid of it by moving the glass through the air,

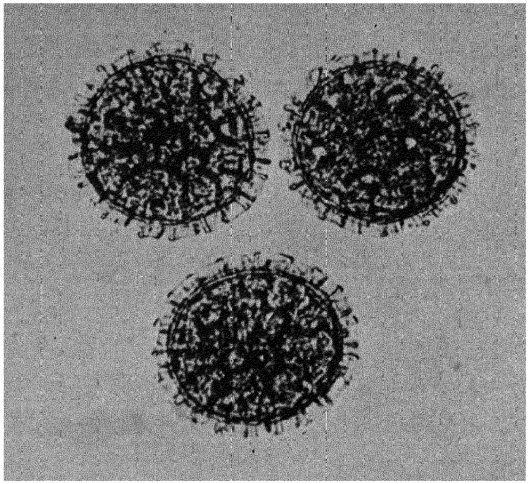


ANTHENS AND POLLEN OF HOLLY $\times 13$

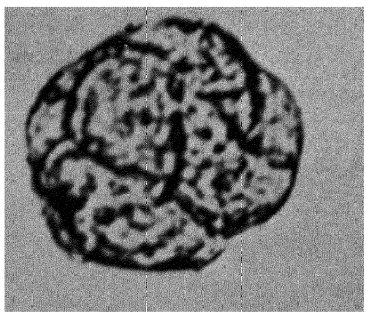


POLLEN GRAIN OF WATTLE $\times 460$

[*Face page* 30



POLLEN OF COBEA SCANDENS × 260



POLLEN OF ERICA

Face page 31]

especially the air which is near the fireplace. Not only is there a current there, caused by the draught up the chimney, but naturally enough the air will be warmed.

Always keep the lenses covered, preferably under the case described, and try not to leave the tube with either end open, or dust will find its way in and prove rather difficult to get rid of. Despite all your care you will find that though the objectives keep fairly free, the eye-piece will not be so fortunate. Specks will appear whilst you are at work, and almost certainly you can say they are upon the eye-piece. Keep a fine camel-hair brush for cleaning this (and the objective should it need it). As a rule the camel-hair brushes sold for paints will serve, but it is a good plan to cut the hair straight across, making it as square as possible instead of the usual pointed finish.

The dealer in microscopes will be able to sell sections of specially prepared wash-leather for polishing lenses; it is essential that such leather should not be used for anything else but the glass.

Those, then, are the hints which should help the novice with his microscope. If they seem to make rather a long list, remember that to begin right is to achieve success, and, as with many other things, want of care may spoil for you one of the greatest and most fascinating of hobbies.

CHAPTER IV

THE MICROSCOPE AT WORK

MUCH work with the microscope has necessarily to be done after sunset, or, if in the day time, when the light is not at its best. In addition, some work must have artificial light in any case; this is particularly true when the microscopist is working with high powers, owing to the peculiar nature of the subjects. Direct sunlight is barred, yet the observer will get as near to the window as possible, and he should see that there are no shadows cast by the framework of the window, nor by its curtains.

For artificial light various kinds of lamps may be used, many amateurs getting quite good results with cheap paraffin-oil burners. Such lamps are rather messy as a rule, and, if one has gas or electricity available, it is better to depend upon such sources, the flex of the latter allowing a good deal of latitude in its use. Again, the optician will often have in stock one of those excellent, but by many considered obsolete, oil lamps designed and used with great success by the microscopist of twenty years ago. Such a lamp is particularly welcome for the fellow living in the country, where neither gas nor electricity is available, or, again, for one who has his own particular den down the garden, where

neither of the more modern types of lighting has been extended.

A very useful fitting for use with the microscope, either with day or artificial light, is popularly known as the bull's-eye condenser, often called the bull's-eye for short. Its main use is in the focusing of the light from a lamp—or again from the window—upon something which it is desired to examine by reflected light. It might be added that the object will almost invariably be a solid one. The bull's-eye is a thick plano-convex lens, almost hemispherical, mounted upon a sliding pillar, which has a universal joint, the pillar being set into a substantial stand, usually of metal.

Some little experiment will be necessary with the bull's-eye before the best results are attained, and quite a number of amateur microscopists do without the apparatus. It is well worth having, however, and many quite good second-hand instruments of this class are upon the market, differing in some cases from the description given above. Another use of the bull's-eye is to produce by its means, as nearly as possible a parallel beam of light via the flame of the lamp. This flame should be reflected to the mirror of the microscope from the bull's-eye.

We have now to consider the best means of working the usual type of microscope purchased for home work which is not of too exacting a nature. It is a great point to get everyone in the household interested in what is going forward. It has been assumed right through that the work is being done by the young man of the family—for man, read

boy if need be—and therefore the descriptions have been given without too many technicalities. But the microscope is such a joy to the owner that he or she will want to share its wonders—we must always include the girls with the boys nowadays; they simply will not be left out.

Let us assume that the bulk of the work will be done in the living room, and that, in normal circumstances, the apparatus will be kept there. It is an excellent plan to make a large wooden tray with a beaded edge. Sometimes such a tray is already in the house with handles fitted. If this can be spared it will save the need for making one. Assuming that one has to be made, the best plan is to get an oblong-shaped piece of three-ply, about two feet by one and a half. Surround it with strips of well planed one and a half inch beading. This should be stained and varnished, but not the rest of the wood. A pair of handles are best purchased from an ironmonger's, so that the tray may be lifted quite easily and without shaking the instrument or the objects which are placed upon the slides upon the stage.

The floor of the tray should be lined with one of the following—all of them good: green baize, cork lino (thin), or oilcloth, or again—and this is excellent —thin rubber sheeting. The first-named is not so efficient all round because we must remember that some of the objects brought for examination will be wet, and quite possibly they might stain the green baize, and so spoil its appearance. There is also the fact that it will retain liquids if spilled.

It will be found that the ordinary table height is quite good for working purposes; if, however, you want to stand and not stoop too much, a box, or some books, may be placed upon the table upon which your tray can rest. The tray will provide accommodation for not only the instrument and the detachable gadgets used with it, but for a portable lamp if necessary, and, particularly, for the boxes of slides, etc. Moreover, the handles will allow of the tray being lifted for passing round the table, though, on the whole it is better to invite your company to come, one by one, to the position at which you are working. This will be necessary if you are using a gas or electric lamp. It is a good plan to use green baize, or thin lino, for the bottom of the tray, so that it will not scratch the polished top of a dining-room table. It is wise to make no difficulties for yourself with the lady of the house!

Now all should be ready except your objects for examination. But we shall have to indicate more closely—and at length—what these may be later on, so, for the present, we will assume that you have one only for examination, and that our purpose is to indicate something of the use of the gadgets upon the instrument you happen to possess. Let us suppose that you have secured the wing of the familiar but destructive daddy-long-legs—a very beautiful object, by the way. This will have been mounted upon a glass slide for ease in manipulation. See that you are all right for light, then place the slide upon the stage, in the centre, and proceed to focus the objective, using at this stage only the

coarse adjustment; do not trouble about the fine adjustment at present. In many instances it will not be required, and the less you have to trouble your head and hands with at the outset, the more will be your own and the enjoyment of others.

Some microscopists are inclined to be fussy with their experiments; some are even bad tempered. This will never do, for there is no hobby which requires so much patience and good temper. Bad temper has a devastating effect on the rest of the company, and you and your instrument will be voted an awful nuisance, until the point will be reached when anything that you can accomplish will have no interest for the rest of the household. So take to heart this friendly warning, and be sure in your own mind that messing about with the adjustments unnecessarily will probably lead to the very contretemps you would give a good deal to avoid.

There is another word of caution relative to the adjustments—coarse and fine; it is that you must learn to balance the pressure you put upon the screws. If you think of the delicate nature of these adjustments, and how beautifully the screw movement must be poised, you will appreciate this caution and the need for balance between the finger and thumb. There have been cases where a great deal of harm has been done by the novice turning the screws with an unbalanced movement. It is a good wheeze to make all these adjustments before summoning the rest of the household to admire the beauties which the lens is now disclosing. They, if left to do the

adjustments, may do the very damage against which it is our purpose to warn you.

It has been said that the greatest asset which a microscopist can possess is the delicacy of his touch; it is even more important than good eyes, for whilst the eye may be helped by the lens, the touch cannot. Care and practice will assuredly give that delicate touch to everyone who has the patience to attempt it.

A little careful manipulation is needed with the mirror, the one to be used for low power is the concave, and also the apertures, to get your light right: this comes only with practice. Again, the great point is to avoid a glare of any kind. Some experts advise that carefully manipulated sections of cardboard can be used advantageously in connection with the diffusion of light. Only by careful and repeated experiment can the best results be obtained when artificial light is used, and nothing can be written which will help so much as the constant trial of various lighting experiments made with the apparatus. Some experts advise that a blue glass shade should be used with a lamp that is inclined to be too powerful—but much must depend upon the lamp.

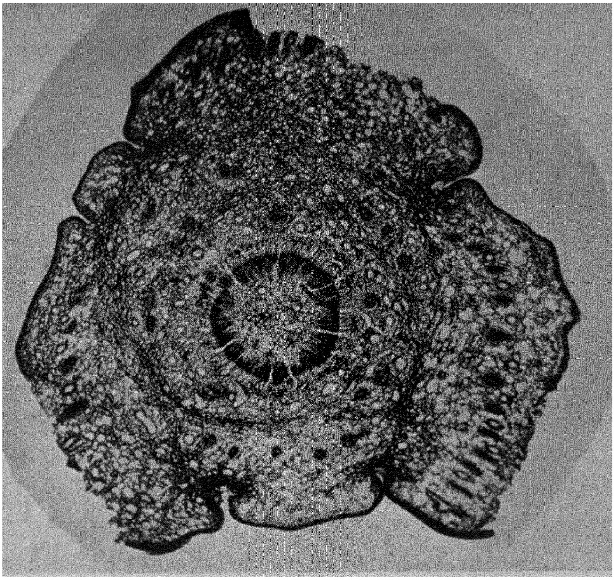
Still another plan to subdue the light is to employ a circular disc of very fine ground glass, which will fit loosely in the stage aperture, or under-stage fitting. This should rest upon the diaphragm plate, actually coming just below the level of the stage. Some microscopists, after many experiments, suggest that the disc of ground glass can be supplemented

by a series of other discs, whose main colour will be blue, but of a variety of shades, ranging from light to navy. There is no real need for these additional discs, but they are indicated for those who wish to make the fullest use which an alteration of colour will give.

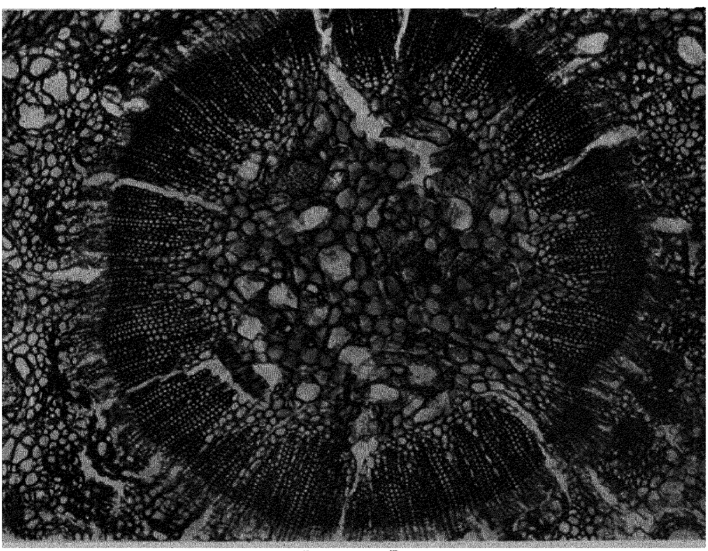
A very simple way of getting the various shades without the trouble of purchasing several discs is to obtain coloured tissue paper of the colours mentioned; cut discs of these shades and then place the desired portion on the ground glass, which we have suggested as really desirable. The net result of any of these experiments will be to show up, in the sharpest relief possible, any object which may be under examination; in addition, the light used will be toned down to a very comfortable degree. If none of the glasses or papers are available, some ordinary tissue paper may be employed with good results.

There is a word of caution necessary to the beginner on the score of what is called racking down a high power upon his slide. Many a slide has been cracked by the eagerness with which the novice gets to work with his quarter-inch scale. We have already suggested that this should be left for the future, and the half-inch, or inch scale be used for the present. But there have been cases where the slide has been cracked, and worse still, the lens itself has been injured, by racking down in a careless fashion, the carelessness being due to anxiety to get the best results.

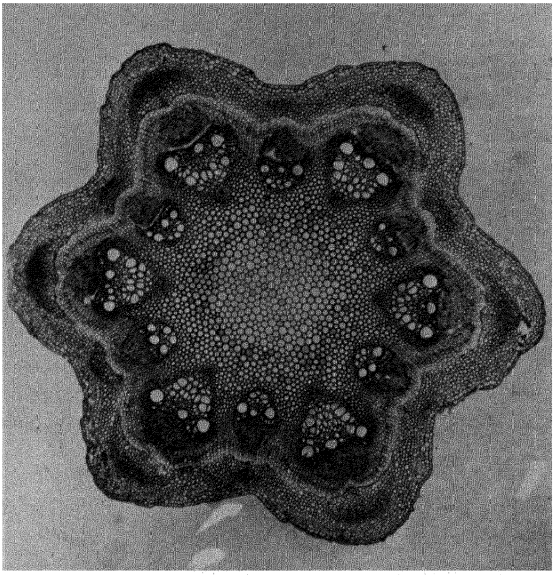
Talking of slides brings the remark that you must



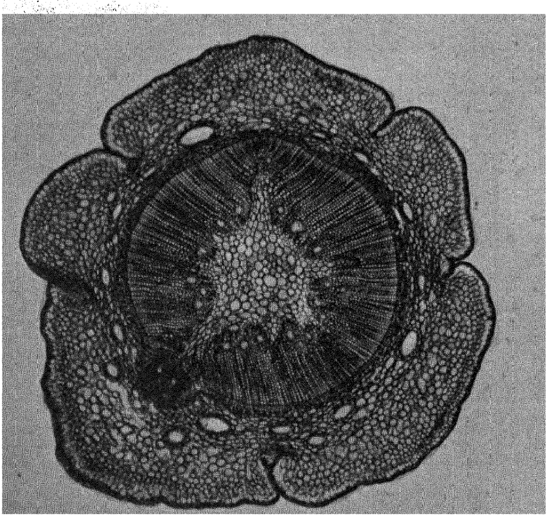
Stem of Monkey Puzzle × 11



Stem of Monkey Puzzle × 55
This shows the detail of the centre of the top picture.



STEM OF CLEMATIS ×20



STEM OF PLANT FOUND BY THE SEA SHORE
(*Pinus Maritimus*)

Face page 39]

so arrange them that whilst they can be moved easily backwards and forwards on the slide they must not be easily shaken off, or even dislodged upon the spot where you have placed them by a mere shaking of the instrument. On most microscopes this is provided for by a pair of adjustable clips. Still thinking of slides. Many of those which you have made up for microscopic use will, on first examination, seem to offer very little of interest, and you may be inclined to scrap them forthwith. Do not do so; there are quite a number which will not prove of great interest all round, but they may have —and probably will have—a corner, or a section, that is well worth while preserving for future use.

Do not forget that what may not interest you particularly may prove of the greatest attraction to some of the household, or to visitors. Thus, whenever a slide is discovered which possesses only a partial interest—that is to say that one section only of it is well worth while, mark that section by a strip of gummed paper, preferably by two gummed strips enclosing the point upon which you want to focus.

You will find that friends are always keen on variety, so that no slide should be scrapped if it has something really well worth while preserving, although the whole is not up to standard.

A refinement for the ordinary type of microscope, which has within recent years been brought within the range of most pockets, is called the nose-piece. Whilst most amateurs (and amateurs is here used and throughout to indicate the person who makes

microscopy a hobby, and has not to use the instrument to get his living) will not trouble about the nose-piece, it is almost certain that the really enthusiastic microscopist will want to add one to his equipment. Get the simplest kind possible. They are made to take two, or even three objectives, the latter being rather heavy and cumbersome in action.

The double nose-piece will be the most usual form used by the amateur. It is very easily operated, and it will enable the worker to pick up objects when working with the higher powers of the instrument. It is particularly useful when the $\frac{1}{4}$-inch scale or less is being used.

In the older instruments the nose-pieces were often unsatisfactory, and many a beginner has scrapped the fitting forthwith, but, within recent years, this accessory has shared the wonderful improvements made in all details of the microscope.

CHAPTER V

SOME USEFUL ACCESSORIES

A FIRST essential to good work with the microscope is some kind of dissecting apparatus. On his journeys abroad the microscopist will be constantly on the look out for specimens; these may be of the animal, mineral or vegetable world. He will certainly carry a pocket magnifying glass, and this will enable him to dissect the objects which he gathers, either on the spot or else from the specimen box which will always accompany the magnifying glass. But there is one great drawback with the pocket magnifier; it takes up the entire use of one hand when both are really necessary for the work of dissection. This must always be done carefully, or the best results will not be obtained. How can this difficulty be overcome? It may be surmounted in two ways, viz: by purchasing a dissecting microscope, or by making one. Let us see how one may be manufactured at home from the cheapest materials possible. Just as the simplest microscope may be made at home for a slight expenditure, so may the dissecting microscope follow, and, mainly, it is built up by the same methods.

First, there is the base of the instrument to be thought about; this may consist of any available

block of wood, preferably fairly thick—say a couple of inches—in order that it will give stability, and it need not be more than six or seven inches square. It may be oblong or circular, which means that practically whatever wood you can lay your hands upon may be pressed into service.

Next comes the upright, which may be fashioned from wire, something of the same gauge as that used for the domestic skewer. It must be stout enough to stand up without bending under a fair strain. It should be at least eight inches long and not less than six. Another piece of wire, considerably thinner, will be required to form the arm. A cork should be forced down upon the upright piece of wire to form a base for the arm of the fitting, the wire being twisted firmly round the cork at one end, whilst at the other it is turned to form a right angle. The cork, by the way, should be bored very carefully so that whilst it will slip up and down the support it will not slide down of its own accord. The end of the arm should be filed to a point to pass through a similar hole, which will be bored through the handle of the pocket magnifying glass. Next a small piece of cork sheeting, or even cork lino, can be fixed upon the base of the stand upon which objects may be laid for dissection.

It will be found that the sliding cork will allow of the lens being focused upon the base. This completes this simplest form of dissecting microscope, which, by the way, may be used exactly in the same way as the simple home-made microscope previously described.

Better work may be possible if some sort of lighting is arranged for. This, too, is easy, assuming that some of the other accessories of the microscope have been purchased. Thus, the bull's-eye condenser (described elsewhere) may be pressed into service, and, by its means, the light from a lamp may be concentrated upon the base of the stand. Or again, lacking the bull's-eye condenser, a mirror may be so arranged that the same effects are obtained.

The great point with this dissecting microscope, made for a few shillings, including the magnifying glass, is that both hands are free for the delicate work of dissection. The magnifying glass can be removed for carrying in the pocket. Assuming that this is already in the possession of the microscopist it is obvious that the whole cost of the apparatus mentioned is less than a shilling, even supposing the materials have to be bought, and, quite frequently, they will be found amongst the lumber which every workshop and house accumulates.

It may be that funds permit something altogether better than the home-made affair described. Then it is advisable to see the stock of an optician and decide either upon a new or a second-hand instrument.

There is a good deal to be said for buying second-hand, since the money saved between such an instrument and a new one may be laid out advantageously upon further and very desirable accessories.

It may be asked what is about the price of a really

good dissecting microscope, and what advantages will it have over the one which has been described. A first-class set would run away with quite five pounds if bought new, but remember what has been said about the possibilities of second-hand apparatus.

A typical dissecting microscope will have a pillar and stand cast in one piece, with rack and pinion fitting for easy focusing; in addition, the lens arm is jointed, so that the power of the lens may be brought to bear upon any portion of the stage. In the instrument we have in mind the lens-arm is arranged to carry Aplanatic magnifiers in dissecting mounts, and it also possesses hand rests, which are of great benefit to the worker.

Then there is the happy medium between the home-made instrument and that described above. This consists of a polished wood block, fitted with an opal reflector and a plate-glass stage. To allow of the ordinary pocket magnifier being used with the stand, there is an adjustable holder provided.

Such a set may be purchased for ten shillings without the pocket magnifier; this, we assume, will already have been purchased. If it has not, the best plan is to buy one of the triple-lens variety; thus the whole outfit will not cost more than fifteen shillings.

The art of careful dissection for the microscope can scarcely be taught by the written word, yet we realise that there will be many a microscopist working away on his own behalf, perhaps in a village where

there are no others interested in this absorbing hobby. Quite possibly there will be others, but such is the nature of the pastime that there are no clubs to join, and as a rule, the microscopist works away in his own den, and rarely does he make known what he is doing beyond his own immediate family circle.

To illustrate this we may relate the story of two accomplished microscopists working next door to each other for many years without either having the slightest suspicion that they had this common interest. They were both business men who had to catch a train to town each morning. But whereas one had to go early, the other preferred to go late. Thus, in a matter of ten years they travelled up to town rarely seeing each other; they travelled back by different trains, and only at the week ends did they so much as catch a glimpse of each other, and then only to exchange a word about the weather. Both were rather shy sort of fellows, and so they might have gone on had it not been that Mr. A . . . was seen by Mr. B . . . one day, from an upper window, going from bush to bush, and transferring something from each to a box, which at once suggested a microscope to Mr. B. . . . At the first opportunity, which happened to be some weeks after, the subject was broached, notes compared, and then joint work was undertaken. The two neighbours, who had thought they had nothing in common, found they had this most absorbing hobby. Moreover, they discovered that they had both been at work since they were boys. From the chance

glance from an upper window, a close friendship was formed, and many a pleasant hour was spent in joint observation and experiment.

So we come back to the point of what to dissect, and how to dissect it. The easiest and best object to begin upon is undoubtedly a flower. Even without any knowledge of botany the task is easy, but it is strongly advised that a cheap and well written book upon botany should be obtained and read carefully. It should be kept in a handy position, so that it can be carried out when specimens are sought in the garden or countryside, and then it should never be far from the microscope when work is going forward upon botanical specimens. The added interest that even a cursory knowledge of botany will give to the microscopist is difficult to appraise.

It is certainly of great moment. If you should be inclined to think that botany is a dry subject, you may rest assured that bringing the microscope to the study of flowers and leaves will make it quite a favourite pursuit; indeed, it is difficult to see how the botanist can avoid the microscope in his work, just as it is impossible to believe that the microscopist can get along without the thousands of growths which will add so much to his enjoyment, so much to his knowledge.

The advantage of beginning dissecting with a flower lies in the fact that many of them can be handled quite easily without the aid of the dissecting microscope or hand glass. Even so, unless one has a slight knowledge of botany, it will be difficult to

classify the stamens, sepals, petals, and pistil of any particular flower. Indeed, one cannot tell one from the other, and thus, when placed on the stage, confusion will result. With quite an elementary knowledge of botany, however, it will be possible to classify and arrange the various portions of the flower, and it is an exceedingly good plan to mount them on a card, writing beneath the names of each part. Whilst this work may be accomplished quite easily with the larger flowers, with the unassisted eye, when one comes to such minute but very beautiful flowers like the Forget-me-not, aid will be needed from the dissecting microscope or magnifying glass, preferably the former, for reasons already given.

Then, under the lens proper, we shall watch how beautifully formed are the stamens, with their antlers, and the wonderful details of the pistil, with its marvellous arrangement of reproductive organs. From flowers to insects seems a natural step. No one need have any compunction in killing a blowfly and bringing him to the microscope, for he is a pest which seems to be greatly increasing, and is capable of spoiling the family joint in a very short space of time.

The instruments used for dissection have been noted earlier, and most of these will be needed when we come to the dissection of this wonderfully complicated mass of insect-life. Having killed the creature, he is pinned to a piece of cork, or similar material, and then, section by section, his body is cut up. Take care to get the wings first, and these should be mounted forthwith upon a slide. Follows

the head, the legs (and take care to get the eyes and tongue as separate items for examination), and then pass to the internal anatomy.

Some experts say that the latter section of the blowfly cannot be dealt with effectively in the air, and that the cork should be weighted and then placed under water. If you are ready to go right ahead with the dissection of the body, undiluted water will do, but if you have to postpone this work until a suitable opportunity presents itself, a four per cent. solution of formalin should be employed to keep the body in reasonably good fettle. When this is done each detail should be mounted on a slide, labelled, and retained as a permanent detail for your case.

The procedure to be followed in mounting specimens will have to be dealt with at considerable length later on.

It is strongly advised here that, at the outset, the new-comer to the microscope who wants to make it a very real hobby should concentrate upon one branch of research—or observation. There are several reasons to urge why this should be the case, not the least being that, as a general rule, greater interest will be engendered. Although the microscope offers—and this is one of its chief advantages over other hobbies—an almost endless variety of subjects, it is only too true that one may become a muddler instead of an expert. On the basis that anything worth doing is worth doing well, we strongly recommend the concentration upon one branch—*but only at the outset.*

Assume for the moment that you should choose botany; do not be content until you have learnt all the things that matter in connection with botany as seen by the microscope. By concentrating upon it you will learn to become expert with your dissecting, with your observation, and, more important still, you will learn all about your instrument, its limitations, its glorious possibilities, and where failures may be expected.

In all this we would not lay down a hard and fast rule. Thus, it may be the case that you lose interest temporarily in botany, and feel inclined to sell or put away your microscope. In such a case it is permissible, and very desirable to explore other avenues, and bring to your apparatus anything which can give you pleasure and entertainment, even if little knowledge may be gained thereby.

In no case should the microscope prove a form of drudgery, and if it should happen that your time is limited, and that the study of any one branch would prove irksome, by no means say that the microscope is of no use to you, and that you will not embark upon the hobby.

Everyone must be guided by his or her circumstances, and just as one reader will delight in the detective yarn and gain real enjoyment from it, another will wish to study biography and get just as much enjoyment out of it. But there will be the leisured and general reader to whom both classes of literature will appeal, and to whom other branches will also prove alluring. Such a reader will, however,

almost certainly try to make himself master of one subject on which he will feel he can speak with some authority. So with the microscope, and it is again stressed that one subject at a time, well studied, will lead to a greater enjoyment of others when the time comes to go on.

CHAPTER VI

ADJUNCTS OF THE MICROSCOPE

ONE of the principal adjuncts of the microscope is the condenser, and if the best results are to be obtained from the instrument it is necessary that something should be known about the condenser and its uses.

The condenser is frequently omitted from the cheaper forms of microscopes, but, as a rule, it is possible to add it later and get some much improved results thereby.

Most of the cheaper kinds of microscopes are what are termed plain tube-fitting; to these a condenser may be added quite easily, but it is essential that it should be able to slide up and down freely, yet not fall to the bottom. If, however, the microscope has a sub-stage, the introduction of the condenser is easier still. The real use of the condenser is to concentrate, or to condense, the light upon the object to a much greater degree than can be accomplished by the use of the mirror alone.

One of the best known is the Abbé Illuminator, and it costs something over a guinea new, but may often be picked up second-hand. It is necessary, of course, that before buying you should be sure it will suit your instrument.

Assuming that the condenser will slip into the under-stage collar, then it should be so arranged that the outside surface of the top lens comes quite flush with the surface of the stage. It should also be in contact with the under side of the object. The lamp must now be placed from four to five inches away from the mirror (the *plane* side is used in this case), and the light is now directed so that it comes through the condenser. Afterwards the object is brought under focus of the objective in the usual way.

Now for careful work with the condenser. The iris diaphragm is almost closed, whilst the condenser is moved very slowly downwards in the collar of the under-stage until the flame of the lamp is reflected in the field, appearing as a band, or streak, of light between two very definitely dark portions. Do not forget that it is the edge of the flame which is turned towards the mirror, and that care should be taken to adjust finally the diaphragm to get the most suitable aperture for the work in hand.

The great advantage of the condenser will now be found, enabling capital work to be done, especially with the medium and high-power objectives; these always give their best definition at a single point of the field. It is upon that point that the light must be concentrated.

It may happen, however, that the observer is anxious to light up the whole field; in this case the flat of the flame should be turned to the mirror instead of merely the edge. An alternative is the use of the bull's-eye.

Most expert microscopists consider that the condenser should not be utilized with objectives having a lower power than half an inch. Some others recommend its use, but with the top lens of the condenser temporarily removed in order that a larger field of illumination should be available. Again, it is possible to improvise a condenser with a spare lens if one is on hand of suitable size for fitting into the collar of the under-stage. It should also be of suitable focus, and it will be found that the image is greatly improved by the use of this arrangement.

Then there is the employment of what is called the dark-ground illumination. Some very remarkable and beautiful results may be obtained by this procedure; this is especially true if the objects brought to the microscope are of a highly transparent character.

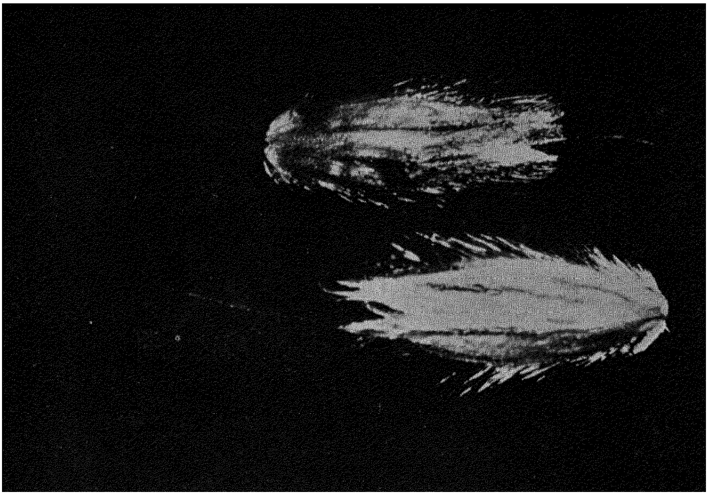
The black background is obtained by a condenser fitted with a series of stops of blackened metal, which again are fitted into a carrier which can be swung out, in order that a stop can be inserted after which it is swung back into its normal position, most Abbé condensers are so fitted. The effect is to cut out the central rays of light which would, in the normal course of events, enter the objective. The black background is thus obtained, and the object is thrown up clearly against it; at the same time it is lighted in such a way that examination becomes not only easy, but exceptionally interesting. Such minute objects as are gathered from the seashore, the pond, and the more minute details of a leaf are specially suitable for treatment in this fashion, and will well

repay the extra expense and time taken with a condenser so fitted.

It may happen that you may have acquired one of the older types of apparatus embracing the fitting known as the spot-lens. Quite good work may be done with the older type of apparatus; indeed, some experts recommend that where the spot-lens is not supplied with a microscope, it should be obtained, notwithstanding the fact that, for all practical purposes, the spot-lens is included with the modern condenser. Its special attribute, however, is the ease with which it is manipulated. It has a long focus, and for certain subjects which cannot be placed on a slide, the spot-lens is very popular.

Another very useful accessory which may be added to the microscope is the Polariscope. It is made up of two Nicol prisms, fashioned from Iceland spar. One of the prisms is so mounted that it can be slipped without difficulty into the collar of the under-stage, where it may be moved round by means of the milled head. This prism is usually known as the polarizer, whilst the other is called the analyzer. In some cases the latter is made to rotate instead of the polarizer. It is mounted in two different methods, either of which are effective. The first is where the analyzer is fixed above the eye-piece, the second where it comes on to the nose of the tube above the objective.

The polariscope is used to split up the light in such a manner that some of the objects under examination give up remarkable colour effects. The lighting, it should be explained, is effected by means of the mirror and, as the prism is rotated, the results



ALEPECURUS PRATENSIS SEEDS $\times 9$

SEEDS OF SWEET VERNAL

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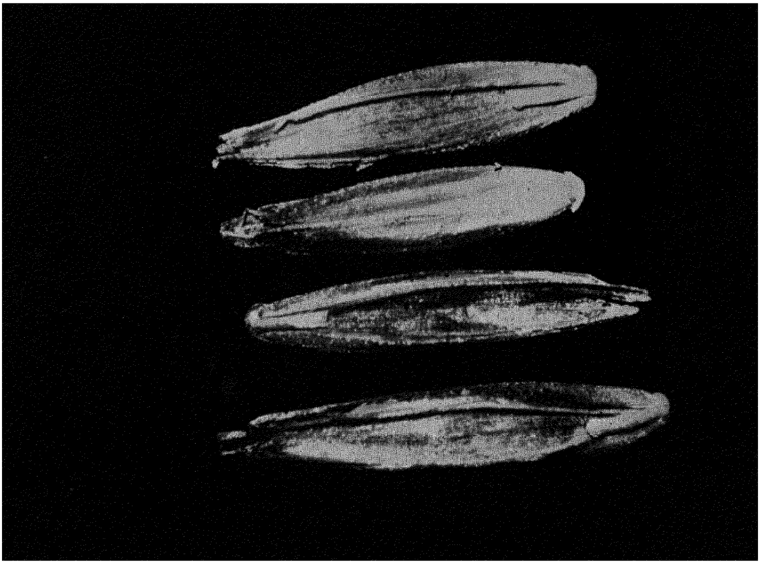

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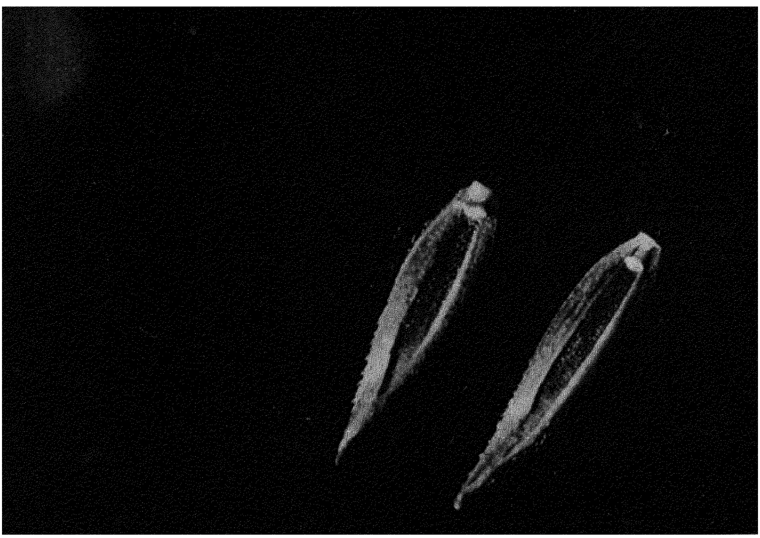


Face page 55] CRESTED DOGTAIL SEEDS

obtained are always interesting, and, on occasion, really very wonderful. Some of the objects which specially lend themselves to careful examination with the polariscope are starches, rocks, particularly those having crystals, and other geological specimens, also many textiles.

The polarizer has been described as too expensive an accessory for the amateur worker in microscopy. This was undoubtedly true a few years ago, but the apparatus has shared with others a constant cheapening as improved methods of manufacture are discovered. It is by no means a cheap accessory now—if really good, that is. The best advice to be given regarding its purchase is to send for the list of a reliable firm of opticians, and also inquire whether they have any second-hand apparatus. It is unwise to buy a polarizer second-hand unless you know something about the instrument or the person offering it for sale. Many prisms are on sale by private persons which have become scratched, even slightly, in use or in cleaning. This detracts enormously from their value, and they would not be purchased for re-sale by a reputable firm of opticians, hence the need for caution when buying through advertisement channels.

Most microscopists will be glad to preserve, in a readily accessible form, the results of their observations. This is, of course, easy where slides are prepared and stored with suitable reference notes. It is an exceedingly good plan to have a microscope log in which work is entered as done. Not only will it prove a valuable supplement to the slides and

other objects which are preserved, but it will prove of the greatest interest to others, besides making a permanent record of work undertaken successfully. But such a record will lack something, which can be added quite easily if the compiler is at all skilful with his pencil. Unfortunately, for one who is sufficiently a good enough draughtsman for making reliable sketches of microscopic objects there will be a dozen to whom the task is too difficult. Yet it is a pity not to have this pictorial record to add to the written word. To meet this difficulty the *Camera Lucida* has been introduced. It takes several forms, all having the same objective, viz., the projection of images upon paper where the pencil may trace over the lines.

The *Camera Lucida*, in its simplest form, is by no means expensive, and it is recommended that the amateur microscopist should add this with the other items already indicated. As the form taken by the *Camera Lucida* may vary considerably, it is not proposed here to describe its working, especially as instructions will accompany the apparatus.

Do not be put off if you find some little difficulty in working with the apparatus at the outset; it is essentially true of this as with other adjuncts of the microscope—that practice makes perfect. It is also true that the things which add little difficulties in the working of the apparatus invariably give a reward which is well worth the trouble taken. The greatest difficulty which will be experienced with the *Camera Lucida* is the training of the eye to keep both the edge of the camera and the

pencil and paper in view together. One expert says that you must train your eye so that one half of the pupil is fixed on each of the two objects mentioned.

A problem which has puzzled many a young microscopist is how the degree of magnification may be determined. Obviously accurate work cannot be a matter for guessing and chancing one's arm. And although perhaps many workers with the microscope will be content with the fascination which magnification gives, it is practically certain that others will want to go on from strength to strength, as it were. It is the purpose of these adjuncts of the microscope to enable that desirable ambition to be consummated. So that the next adjunct we have to consider is the Stage Micrometer, which is a glass slide having a ruled line, which is marked off into divisions, varying from 1000th part of an inch to perhaps 100th part of an inch wide. In some, and especially those of foreign make, the measures will be given in fractions of the millimetre.

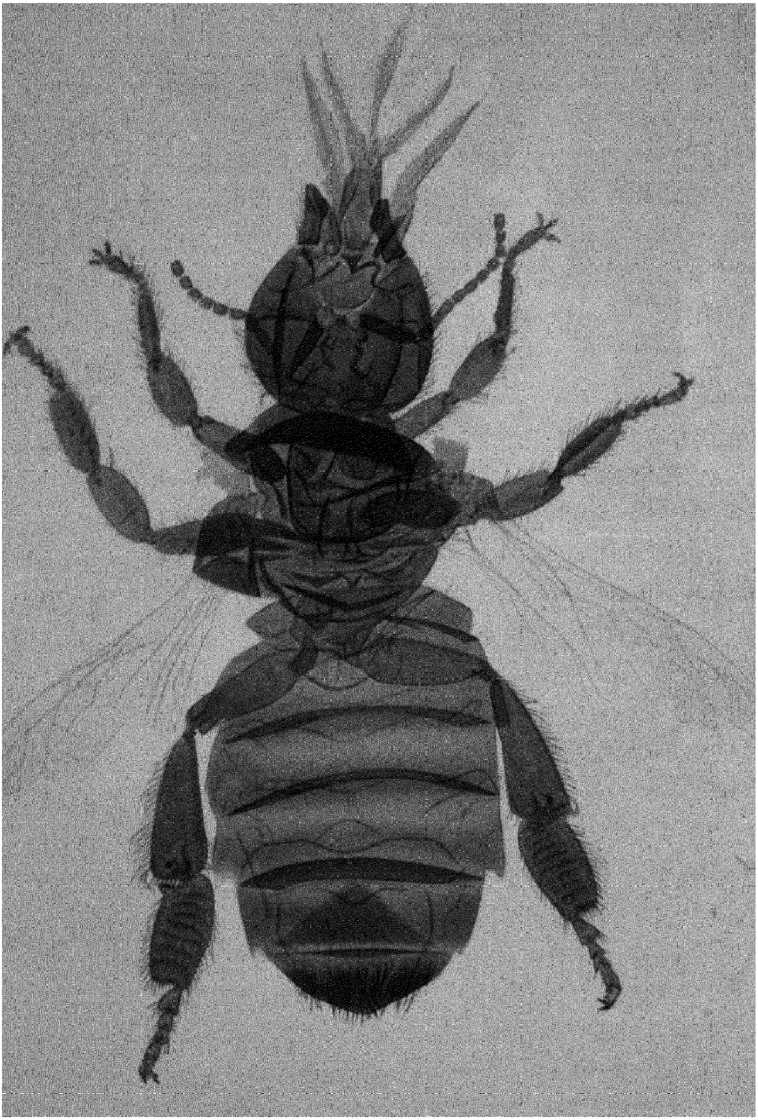
At first sight such minute measurements as 1000th part of an inch seem impossible, and certainly too fine to bother about. One youngster told the writer that he could not conceive such a measurement. But he was convinced when handed a volume of Shakespeare, which, though less than in inch in thickness, contained well over 1,000 pages. For practical purposes it was clear to the boy that the India paper used for the text was actually of less thickness than 1000th part of the inch. "I would

not have thought it, but seeing is believing," said the youth.

The glass micrometer which will allow of such work as that about to be dealt with is not at all expensive. A good one can be obtained for as low a figure as five shillings, but it is desirable to pay a shilling or two more if possible, and get the better class Stage Micrometer, which is used as follows: First, the microscope is arranged for use with the *Camera Lucida*, and it is essential that the distance indicated for the use of this instrument in the accompanying instructions should not be exceeded. Usually the distance between the paper and the tube is just under a foot. The next step is to focus the object, and then the dimensions of the image are marked clearly upon the paper. Next the object is removed and the Stage Micrometer takes its place, and at once the image of the marked divisions is seen on the paper, thus giving the degrees of magnification. In addition, the actual size of the object is shown.

Another very useful little accessory is known as the Live Cage, which is employed with the microscope when it is necessary to put tiny live objects under scrutiny. It is always a pity to destroy life if it can be avoided, and as microscopists are usually rendered more humane by what they learn of animal life, it follows that they will avail themselves of the live cage wherever possible.

It consists of a brass plate which has a circular opening; this is crowned by a rather short brass tube, which contains a disc of clear glass. Upon the



A PHOTO-MICROGRAPHIC PICTURE OF THE HONEY BEE

tube comes a sliding cap, which also has a very thin glass disc. In use the live cage is simple to handle and extremely effective.

You take an object from your tank—assuming for the moment that it is an insect found in water—(and these are easily amongst the best objects)—and place it in the cage, adding, when possible, a little water to make the creature feel more at home and therefore more easily examined. Now replace the cap, taking very great care that the insect is not crushed as you lower it into position; the cage is then ready for your observations.

A cautionary word here. Some microscopists are inclined to leave their apparatus as soon as their experiments are finished, probably having to hurry off. Give a thought to the little fellow in the cage, transfer him to the tank, and, particularly, clean the glasses of the live cage before putting them away. If you forget you will find it more trouble later on, and your next experiment or observation will be delayed. Even when cleaned upon being put into the case, or upon the shelf, it will be necessary to give the glasses a look over before using them again. It will be appreciated that you are examining something very minute under another thickness of glass instead of directly under the objective.

The live cage is by no means expensive, and quite often a good one may be picked up second-hand. There is no need in such a case to feel that previous use has damaged such an adjunct as this: there are no prisms to be scratched as in the polarizer.

Other useful (though not essential) adjuncts are the two micro-telescope attachments made by F. Davidson & Co., 143–149 Great Portland Street, London, W.1, which, as will be seen in the frontispiece, slide into the under-stage fitting of the microscope. One of them is of six inch focus, and this addition converts the microscope at once into a telescope of wonderful range (from six feet to infinity), clarity and depth of focus, and it is particularly useful for studying insects, birds, etc., without disturbing them. The other attachment is of three and a half inch focus and has a very distinct application, for it *bridges the gap* between the microscope and the telescope. Objects too small for the telescope or too large and too rough for the microscope—such as insects before dissection, minerals, pond life in a small tank, etc.—can be examined at distances varying from one to three feet away with variable magnification according to the distance.

CHAPTER VII

MOUNTING OBJECTS FOR THE MICROSCOPE

THE mounting of objects for the microscope is almost as fascinating as their study under the lens. But care is needed for the best results, and although it has been suggested that cleaned off photographic plates may be pressed into service for slides, it will be found better to purchase the prepared slides, which are quite cheap. They range from twopence to sixpence a dozen for the size most usually employed, viz. three inches by one inch. It is safe to say that the better quality should always be used for the more delicate objects, and, if funds permit, it is better to buy only the best. Economy may be found, however, by purchasing dozens of various qualities, and then using the most suitable for the object to be mounted.

Some expert microscopists, if asked for an opinion on the successful mounting of objects, would possibly refer the inquirer to a manual on the subject. Should this book be acquired it is practically certain that the amateur microscopist would be frightened off the pursuit at once; at the best he would decide that he would never attempt the mounting, and would therefore patronize the optician, who will always have a good range of such slides for immediate use.

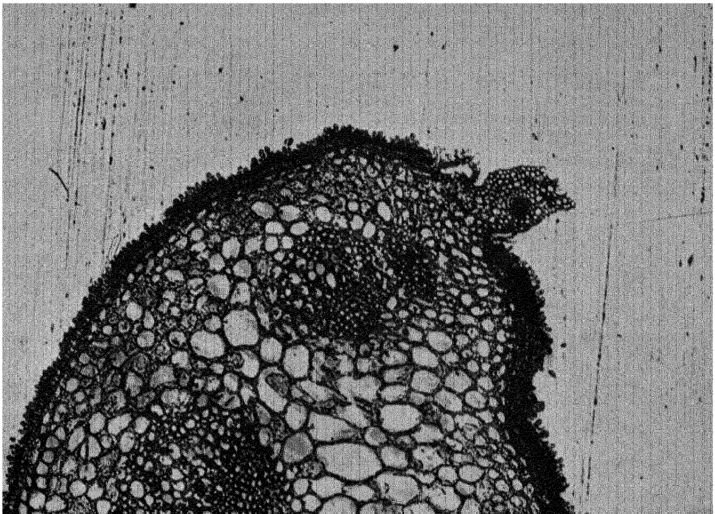
But in all hobbies the chief joy consists in doing as much as possible for oneself; so with the preparation and mounting of slides.

In addition to the glass slides mentioned above, the worker will need some of the following accessories. An assortment of thin cover-glasses, which are sold, curiously enough, by weight—something like four shillings an ounce being demanded. That sounds rather dear until we recollect that the glasses are very small and very light weight too.

The cover glasses are both circular and square, the former having a diameter ranging from about half an inch to an inch.

Another purchase will be a small spirit lamp, usually made of glass, and found in all chemical laboratories, a bottle of good black enamel—this, by the way, is specially made for the purpose, but if any difficulty is found in purchasing it locally, try Brunswick black, which is really very effective, and then a bottle of gold-size is needed.

A very useful and almost indispensable accessory to successful mounting is a miniature turntable, upon which the slide can be fixed whilst mounting is going forward. This can be easily made at home, if desired, though it is quite cheap to buy. The main points in its construction are a block of wood six inches by four, and not less than an inch and a half thick, a disc of aluminium, not more than four inches in diameter. This is bored through the centre and mounted upon a threaded screw, which can be operated by a milled head placed underneath. Clips are desirable to secure the turntable block to



MILDEW FOUND ON ROSES $\times 56$

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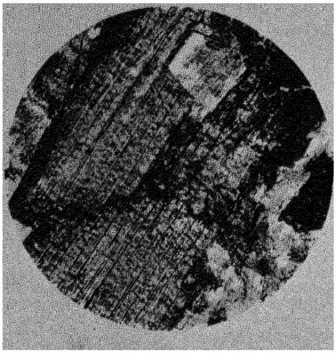
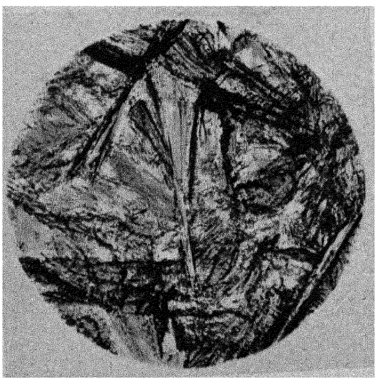


MINETTE. A ROCK SECTION
Observe the strata in the rock.



STEATIC ACID CRYSTALS

the table or work bench. It is essential that the turntable should have a considerable overhang in order that the milled head screw can be got at quite easily, and for this reason the turntable is placed as near to the edge of the wooden block as possible. Strips of rubber can be glued on to the upper surface of the metal to secure the slide, which should be quite firmly fixed and yet should be easily withdrawn when desired.

Forceps will already be included in the outfit, but it is necessary to add two or three fine sable or camel-hair pencils; the former are recommended for good work.

With the above equipment the slide maker is ready for business. Before the amateur slide maker proceeds to important work it is very desirable that he should get in a certain amount of practice. There is nothing to spoil with the slips of glass really, but the best results will not be obtained until first the method of mounting is fully understood; secondly, until the more intricate objects can be mounted in the best manner possible. Some microscopists recommend that the beginner should commence with what is called cell-making.

The first step in this direction is to put a new glass slide upon the turntable, take a sable or camel-hair pencil and dip it into the gold-size bottle so that the pencil is coated. Then commence the rotation of the turntable whilst the pencil rests very lightly upon it. In this way the ring is automatically formed. With due care an even thickness is obtained, and its width should be uniform. It should be the

objective of the worker to produce a neat ring into which one of the cover glasses already mentioned may be fitted. It is a good plan to have the ring with a slightly greater diameter than the cover-glass, so that, when the glass is finally placed in position, there remains a narrow margin of gold-size ring on the outer side.

When the ring is completed the slide must be placed safely away where the dust will not be likely to affect it, and then allowed to dry slowly. If to be used with the thinnest of objects, nothing more will be needed, but if it is desired, as will often be the case, to thicken the ring—that is, raising it—coat after coat of gold-size must be added. Each coating must be allowed to dry off—slowly. There can be no hurrying of the process.

Several slides can be prepared at the same time, and, if desired, when dry various thicknesses can be added. Thus, some can be given four successive coats, some three, others two, whilst a few will be reserved with one coating only.

Now let us suppose we have an object for mounting. Having already captured a blowfly and dissected his body, first removing the wings, the latter—or rather one wing—will be ample for our purpose, we take a slide which has a cell of one thickness of gold-size. Care is taken to cut the wing so that whilst it will fit neatly into the circular cell, it will not move about. It is a good plan to make a square cut as the edges will then engage with the sides of the circle. The slide is already upon the turntable for ease of working. Now, with the sable pencil, run round the top of

the cell with the gold-size. This must be a very thin coating, and the slide is then lifted from the turntable to dry, whilst other work is gone on with.

The gold-size must not be allowed to get quite dry. Remembering the instruction which one gets with the mending of an inner tube of a cycle or a motor tyre, the gold-size is allowed to emulate the rubber solution and get tacky. Now, instead of the rubber patch to which most of us are so used with the tyre, we take a cover-glass, seeing particularly that its inner side is clean, and press it carefully into position, holding it down until certain that it is adhering all round. The sealing of the cell is accomplished with a band of black enamel or Brunswick black. It is then desirable to label the slide, and, after it has been ascertained beyond all doubt that the enamel is quite dry the slide is put away in the position where it can be readily produced when required.

It is very desirable that some satisfactory method of filing your slides should be determined upon at the time you begin to make them. There are many ways of doing this; some ways are expensive, others may be suited to a not too full purse. If funds permit the easier way is to go to the opticians and purchase a cabinet or two as a start, label them up, and see to it that the slides and objects are properly filed away. There is nothing so annoying as when your specimens, mounted or otherwise, are needed for exhibition to a friend as to be unable to find them easily. There have been several cases where, through sheer lack of organization, this fascinating hobby has

been robbed of one of its main advantages—that of interesting others.

There are special cabinets sold for taking slides, and these, of course, are best of all. But any fellow can make one without any real trouble if he can but see the kind of thing needed. The best advice possible—since it is impracticable to describe closely the fitting—is to buy a small filing cabinet for slides, and then make your own when the first is filled to overflowing. One of the best home-made cabinets the writer knows is where a wall cupboard, bought for a few shillings second-hand, has been converted to a splendid fitting. The higher shelves have been sub-divided into a series of racks by the use of thin three-ply wood, and a series of boxes, resembling nothing so much as those used for dominoes, have been fashioned from the same material. These are labelled, and each one contains a dozen numbered slides. Corresponding labels are on the slides, and they are always kept in the same order. Thus, the proud owner of the cabinet simply unlocks it, and you say to him, "Water insects, please," and promptly he lifts down one of a series of boxes, and asks which slide you would like, or, more usually, he hands you a card showing his exhibits classified and asks you to select one or two boxes. Or again there are cards indicating what trays of specimens he has for exhibition. The trays vary from the tops of tin boxes (which he has enamelled various colours for easy identification) to some neatly stained and varnished three-ply wood affairs. These are quite easy to make, consisting merely of a three-ply base sur-

rounded by a beading of the same material, the beading being half an inch in depth.

This same fellow spotted that cigarettes were being sold in handsome unpolished oak boxes. Not a smoker himself, he contrived to persuade those of his friends who were to buy the brand of cigarettes which were packed in these fine boxes; then he bought some himself and kept the boxes, exchanging the cigarettes in them for the boxes which his friends had purchased. In this way he acquired some very suitable "carrying boxes" as he calls them. These he has fitted with a series of very thin aluminium divisions which add considerably to the capacity of the box, and something like a dozen slides are accommodated in two tiers, the false floor being made with three-ply. In such boxes the slides travel safely when he needs to take them to friends also interested in the microscope, and who happen to possess their own instruments; at the same time the cigarette boxes relieve the strain upon his cabinet. The lower shelves of the cupboard are reserved for the trays, and a complete catalogue of specimens with denoting numbers, is pinned on the inside of the door. This is typed, and then mounted upon cardboard, so that the catalogue can be lifted down for examination, and additions when needed.

All this may seem to indicate a great deal of work, and perhaps you may think it unnecessary. But if you could ask anyone who had undertaken this work, they would say that the first task, and regularized work after, saved them hours in the aggregate.

There is one very important detail in connection with the mounting of objects on the slide that should be especially stressed for beginners. It is that care should always be exercised in dealing with the gold-size. Many a beginner, in his anxiety to get work done, has failed to notice that the cell walls were dry, and has thus gone on with the cover-glass fixing, too often with disastrous results. All the work has to be done over again; it is therefore good advice to give when we say go slowly.

Another point is important; some beginners have taken great care to see that the cell they have built up is perfectly dry, but have not been so careful with glass slide or cover-glass, and once, at least, it is on record that the object itself was not dry when placed in the cell. Within twenty-four hours it was ruined. Here comes the great value of the spirit lamp. With the forceps handy, each detail may be held over the flame—not too near it—and thus they are made perfectly dry. Always have a formula in this working, and then mistakes are infrequent. The formula is really the order in which this drying process is carried out; it runs (1) the slide itself, (2) object, (3) cover-glass. Always follow that order, and no mistakes will occur. It is a good plan with the last-named item to pass it actually twice, or perhaps three times through the flame. But the slide and object would probably resent such treatment, therefore it is better not to risk their destruction. It is, however, stressed again that the cover-glass must be absolutely dry.

Some beginners find difficulty in building up the

walls of the cells to a sufficient height. One, in particular, mentioned as his difficulty that the gold-size seemed to spread rather than to increase the height; another complained that it took far too long to prepare the cell by this rather laborious process. Both have the sympathy of the expert microscopist who has found out another way to achieve his ends. He goes to the dealer in microscopic accessories and purchases a few, or perhaps a considerable number, of graded vulcanite rings which can be affixed to the slide with gold-size or other adhesive material (though gold-size is best for all practical work), and he thus cuts out the labour we have indicated.

Still, remembering the fellow who wants to do as much as he can, and in as little time as possible, we suggest another method of making up the cells. It consists in making rings of fairly stiff paper, such as the parchment kind of paper often sold for letter writing. This is cut into strips of varying width, and then to a regular size as regards length. Next a join is made to form the ring, and the next stage is reached. This is the melting of a quantity of paraffin wax and after immersion therein the rings are allowed to dry thoroughly. When dry they are attached to the slide by means of gold-size.

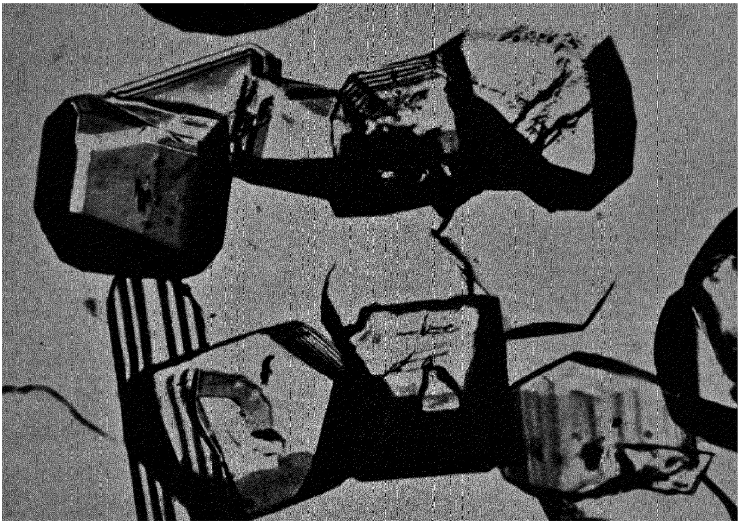
The paper rings are quite effective, and so are those of vulcanite, but, on the whole, we would recommend the building up of the cells for most objects, with resort to the other kinds where a deeper cell than usual is needed.

CHAPTER VIII

SOME GENERAL HINTS

DETAILS have been given of the manner in which simple slides are made, and we shall now go on to deal with the mounting of objects where more care and attention are needed. All that has been written holds good, but there is a word to be added upon the washing of slides. This applies equally to the cover-glasses, whether old or new. Slides are so cheap that those for which the microscopist has no further use may be thrown away, or given to a beginner. But, if economy is essential and time plentiful instead of money, there is nothing to prevent the cleaning off of the slides in hot water and the use again of the cover-glasses. *They must be thoroughly clean*, whether old or new; this is a prime factor in securing satisfactory work. It must be remembered that both slides and cover-glasses are delicate and need careful handling; this is particularly true of the cover-glasses, and we imagine that few will attempt to clean off used glasses. Hot, soapy water is necessary, and the glasses should be dried on some linen, or similar class of material whilst still warm from their bath, and then polished with wash-leather.

Here is a useful hint as regards mounting very minute and exceedingly light objects which would



ASPERGINE CRYSTAL

CARBOZOLATE OF POTASH CRYSTALS

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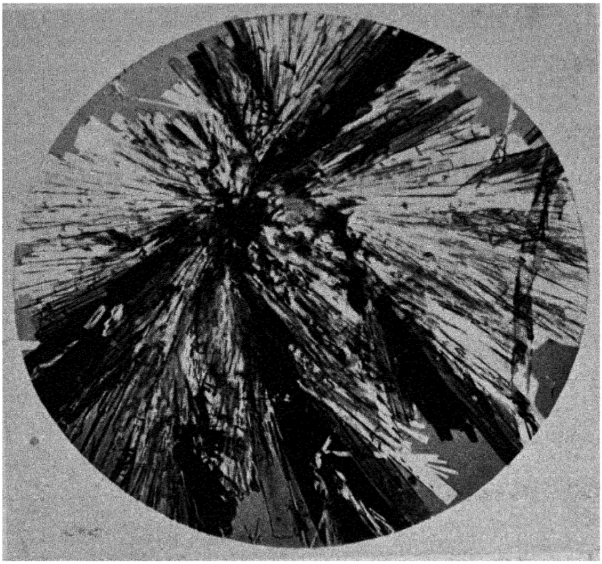
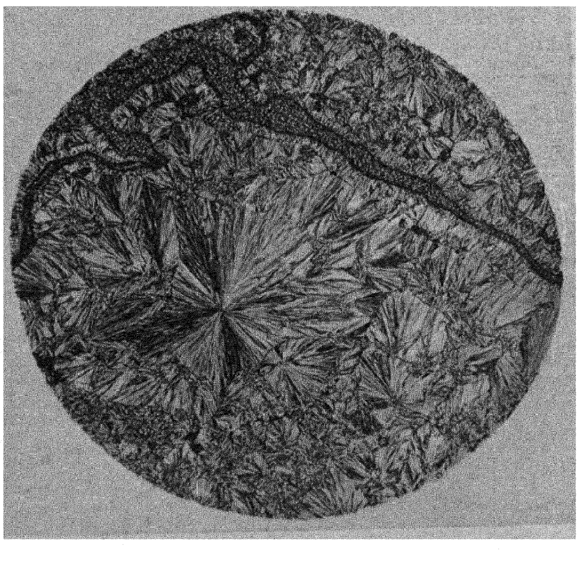


CYANIDE OF MAGNESIUM



CRYSTALS OF DIHYDROXY-BENZINE

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be likely to move into a bad observation position after the cover-glass had been affixed. Think, for instance, of the wings of the smaller kind of flies. When preparing the slide and finishing off the cell, drop the smallest portion of clear gum into the centre of the cell. The most minute spot possible, and it must be spread over the surface of the bottom of the cell in the thinnest possible film. Now here is another hint as to the mounting of the object upon the film of gum. Do not put it there straightway and then seal up; the gum must be allowed to dry first. How then can the wing be mounted? By breathing upon the gum film—that will give all the moisture necessary, and there will not be any excess to harm the object when the cover-glass is sealed upon it.

To obtain a black background is quite easy, and there is no need, as was formerly the case, to make it inside the cover-glass. The best way is to paint a glass slide with dead black, and reserve it for regular use when such a background is needed. It is placed upon the stage under the slide to be examined. If dead black paint is not available, black paper will serve admirably, and there have been occasions when black carbon paper, used for under copies, has filled the need.

The question may arise now—it certainly would later when the beginner had advanced some distance in his slide making—"What about those subjects which *must* be mounted in liquid and remain so? You have stressed all along the need for the exclusion of moisture from the cell and cover-glass."

The reply to this question is that, for a long time, the new-comer to microscopy need not trouble his head about such objects; in any case if they are desired, it would be far better for him to purchase the slides already made up. The experts, who have undertaken this work, are unanimous in saying that it is trying, and that rarely are satisfactory results obtained by the amateur, who is then inclined to become dispirited, and perhaps even to give up microscopy because, in this one respect, he is baffled. This, of course, applies to the newcomer rather than the experienced hand, who has had many years' work with the apparatus.

Even so it is good advice to pass on to both the new-comer to microscopy, as well as to the more experienced worker, that slides of the kind mentioned are better bought than made. It is a branch of the business of supplying the needs of the microscopist to build up high-class slides. Some firms advertise a collection for a certain sum. To the man or boy whose time is limited, and to whom the making of slides must, therefore, be a slow process, taking perhaps months to add a couple of dozen to the collection, this may be a very welcome investment, as much enjoyment may be had from what we might call the lighter side of microscopy with the study of these bought slides. If, however, you went to an expert he would deprecate the purchase of a collection—to the real ardent microscopist it seems to involve a breach of the laws of the game—something like an offside at footer. Mind, he would not say you must not buy slides at all; rather would he

say, "Buy, but only sparingly, and only those which you would find it difficult to make up satisfactorily yourself. Choose here and there, and be fastidious in your choice."

But here is the advice of an old hand who has gone through the whole business, directed specially to the new beginner who wants to have a selection of slides at the outset until he can build up a collection made with his own hands. He says, "By all means buy a collection, and buy it second-hand, if at all possible, in one of the proper boxes containing space for six dozen slides. Never mind if the space is not filled up. Then begin work in making your own until you have filled up all the vacant spaces in the trays or boxes. The next step is to classify your collection into three grades, marking each slide 1, 2, or 3 as you determine its grade.

The first and highest grade will be No. 1, the lowest No. 3. As each slide is produced from your hands grade it. If it falls into grade 3, then you will displace one of the grade three that you purchased; if a grade 2 or 1 the same result is found until all the bought slides of the grade three are displaced. These should be given to some new-comer, and will help him along. In this manner you will get the best of both worlds; that is to say, you will retain the best slides from the purchased collection, and you will have strengthened it by the inclusion of your best work.

With seventy-two slides to work from, plus any objects which you may have unmounted, you will have a reasonably good collection, and then, when

you have got rid of all the slides that do not come up to the standard you have deliberately set for yourself, the formation of another section can be entered upon."

That advice seems sound to the present writer, and it is passed on. It is advice that has not appeared in print before, and it seems rather easier to follow than some which is given in textbooks upon the fascinating subject of microscopy.

In any case, the beginner should keep an ever-open eye for the work of the skilled mounter. Opticians frequently stock some really exquisite slides; the kind of thing that would never fail to interest you or your friends. These are like the pictures one sometimes comes across, the picture that is hung in a position that you must pass several times a day, and which you can never pass without a glance of affection. Unfortunately, these remarkable slides will not be found in one of the advertised cheap collections, nor can it be expected that they should. But there is a certain zest in hunting them down, and adding to a special section of your collection of slides.

It is very good advice to pass on to the beginner again that whatever object is brought to the microscope, particularly the objects which are examined without a slide, should be as small as possible. This is especially true of such objects as sections of fruit, vegetables and food. One item in the latter category readily comes to mind. It is cheese, wherein the observer will search for those wonderful living organisms we call mites. You would certainly not

see them as they ought to be seen if a large piece of cheese were put under the lens. A thin section, cut very carefully and covering the smallest space, is the golden rule, and all objects should be arranged so that they appear in one plane.

The work of the microscopist is always progressive, and in that, perhaps, lies its chief interest. Thus, having said something about the mounting of objects in cells upon slides, and indicated how the more difficult subjects can be obtained, let us pass on to the consideration of the mounting of transparent objects by a different method to that already dealt with. The transparent objects with which we are now concerned are to be made available for examination under transmitted light, and, for this reason, it is necessary to mount them in balsam. This is known as Canadian balsam, and may be purchased in small quantities; a shilling's worth will do very well for a start. The balsam must be dissolved in benzol, and a balsam bottle should be purchased to contain the mixture. This latter is something like a gum bottle and is covered by a glass cover cap. All stores which stock microscopic goods will have them on sale.

In addition, a few other accessories will be required, such as a glass rod, about six inches in length, for manipulating the balsam mixture; this should be of solid glass, and can be bought with the rest of the accessories, and then a mounting-table is essential. Whilst this may be home-made, as with so many other accessories of the microscope, it is usual to purchase this fitting ready for action. If desired to

make, the following hints may be found useful. Obtain a piece of sheet iron, or better still the lid of a stout tin box, about six inches square, and a piece of sheet brass not less than four by three inches. In the brass sheet punch a hole at each corner. Then obtain four 4-inch screws, either of brass or steel, and fix them into the holes which have been punched. When making the holes, make them as small as possible as it is the sharpened end of the screw which will be secured in them. File off these points, and fill up holes if necessary with solder or some other filling.

Take care that your miniature table stands true upon its four legs. It will be found that the flat heads of the screws will make excellent feet, though rounded ones will serve. The spirit lamp already in your possession will then be brought under the table ready for service. An alternative to the screw legs may be improvised from wire, but we do not recommend this unless the amateur worker has some skill in making neat turns and finishing touches with wire.

The use of the mounting-table is to heat the slides placed upon it, the lamp underneath giving the necessary heat. The best base is undoubtedly one with a rim, such as the tin lid already mentioned. This may be obtained from a biscuit or similar box, and, in the event of the lamp being upset, there is far less danger of fire, as the methylated spirit cannot run off on to the table or work bench. In addition to the methylated spirit required for the lamp, it will be needed in the work of mounting as well as

a small supply of turpentine. These items, together with those already mentioned as having been obtained for making the cell slides, will now allow a start to be made on the special objects for which the Canadian balsam is so suitable.

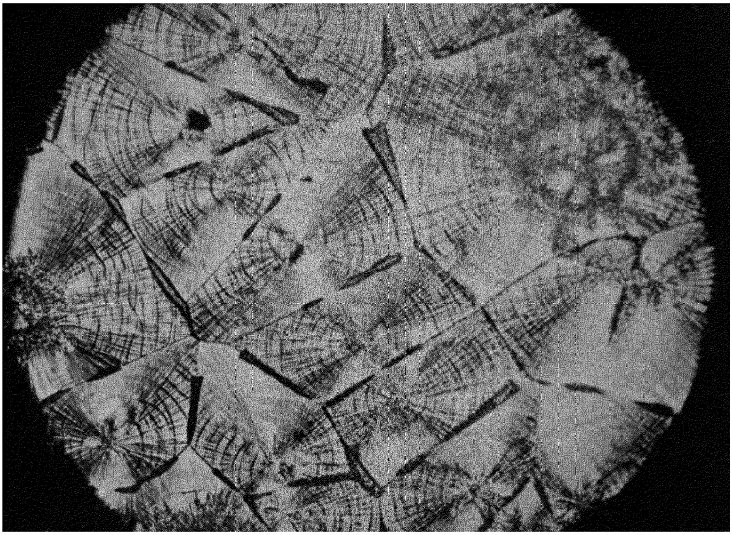
A very important point should be mentioned in connection with the use of balsam. Balsam will not tolerate water in any degree, because it is a purely resinous kind of material. Now, many things contain water without our suspecting the fact. If this is not realized and acted upon at the outset, there will be trouble with our mounting. Here the methylated spirit comes nobly to our aid, whilst it is ably seconded by the turpentine. To make sure that every object with which we deal is free from water, we attempt what is called its dehydration. This is accomplished first, by soaking the object in methylated spirit, and afterwards giving it a final soaking in turpentine. Some objects will not allow either spirit to permeate them; there is no need to worry about these, because if they will not absorb the spirits mentioned, they are unlikely to have water in their constitution.

It might be mentioned here that there may be some who would prefer not to be troubled with the procedure outlined above, and yet feel they would like to try their hand with the objects which balsam is so necessary for mounting. There is no difficulty about this, since many firms have the objects already treated for the amateur worker, whilst there are other amateur workers who will advertise in journals having columns for the microscope. As a rule, when these objects reach you, the only instruction accom-

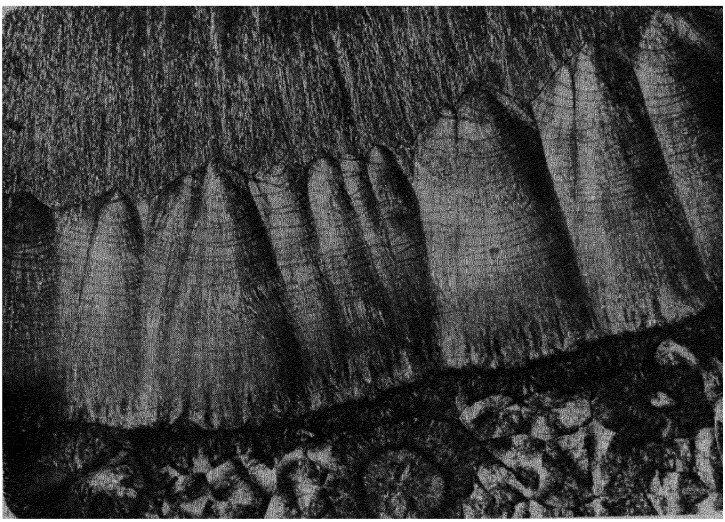
panying them will be to soak them well in turpentine before proceeding with their mounting. If the instruction does not accompany the objects it is a wise precaution to give them this treatment to be on the safe side.

Whether the objects are acquired in this way or prepared at home the next stage is now reached when the slip is placed ready on the mounting-table for its object. It must be thoroughly clean—again and again we shall stress cleanliness, because it is all important, and, unfortunately, the novice does not always realize this importance until he has spoiled unnecessarily some of his best objects, to which he has given perhaps hours of otherwise careful work. See to it, then, that slides and cover-glasses are as clean as you can make them. The spirit lamp is already alight we may suppose, and so the slides can be gently heated upon the brass top of the mounting-table. A question comes here most likely; it is, "How hot should the slides be made?" The best answer is that they should not exceed the heat which will allow of them being handled without gloves and without accident. The balsam bottle has its cover removed ready for work, and, at its side, lies the glass rod; these can all be accommodated upon the base of the mounting-table if this has been made or purchased sufficiently large. It might be added that although some of the shop mounting-tables are sold without a base, it is very desirable to have one; remember the tin lid.

Now we get to work. The glass rod is dipped into the balsam mixture, and a little of it is dropped



Crystals of Hippuric Acid



Hippuric Acid, showing closer detail

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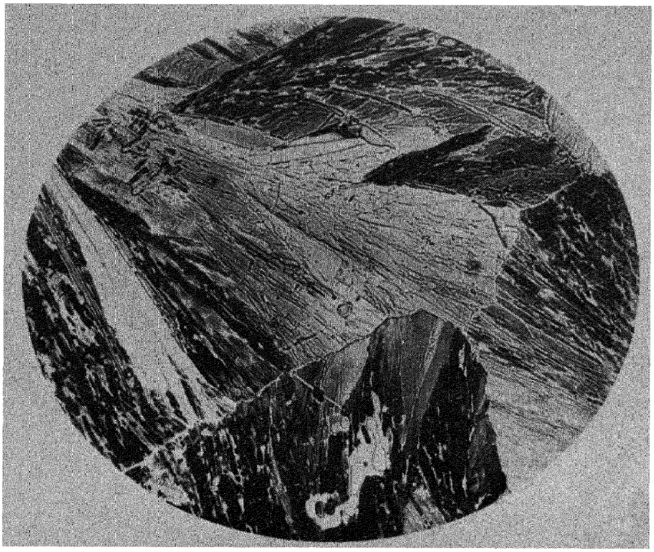

Crystals of Tartaric Acid

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A Section of Coal
Coal Strata Fulesgate.

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from the end of the rod into the centre of the slip. The exact quantity needed cannot be given, because so much depends upon the object you are mounting, and also upon how much you are able to lift each time on the rod. A couple of drops should be ample for all ordinary objects.

Within easy reach is a saucer or bottle of turpentine; if bottle it should have a wide aperture like that used for the balsam. In the turpentine the object is already being soaked. Now, with the forceps, lift it carefully, the turpentine being allowed to drop off to the bottle or saucer if too much is noticed to be clinging to the object. Some objects will be more easily removed from the turpentine to the slide with a needle, or again, as recommended by some experts, by a small instrument known as a section lifter, which costs only a few coppers, and is well worth while adding to the accessories of the microscope. The object is placed very carefully in the centre of the balsam, and, by means of the needle, forceps, or section lifter worked well into the compound.

The pocket glass should always be handy in these delicate operations in order that the work may be inspected from stage to stage. Such an inspection is very necessary at this juncture in order to determine whether there are any air bubbles adhering to the object, and, particularly, to see whether it has been correctly placed in the exact centre. If all is well the cover-glass is now warmed in the grip of the forceps over the flame of the spirit lamp, and then, by an adroit movement, lowered on to the balsam,

care being taken that, whilst gentle pressure is applied, it is an even one all round the glass. There is a disposition for the cover-glass to move slightly and thus a perfect joint is not ensured. To overcome this tendency it is recommended that a slight weight should be applied, and left upon the mounting until the balsam has set properly. Better still, and always recommended by the expert, are the clips sold specially for work of this description. They are quite cheap and are stocked by all reputable dealers in microscopic materials. Care must always be taken to use an even pressure when affixing the clip, as, in many cases, the cover-glass is pushed slightly out of position.

Another point to watch is that the balsam used is quite sufficient to cover, indeed to fill, the entire space under the cover-glass. It is better to use too much than too little; any excess remaining outside the cover-glass may be cleaned off quite easily with methylated spirit. One expert suggests leaving it untouched, as he has found that, in trying to make a very neat job of the finishing off, the methylated spirit has penetrated the cover-glass joint and interfered with the object. But it certainly looks very much neater if suitably trimmed off. Another worker suggests that, although not really necessary, the whole appearance of the slide is improved if the joint is ringed with black enamel as suggested for the slides mounted without balsam; it is a refinement which the particular worker will perhaps like to add, but it is wholly unnecessary where balsam is the agent used for mounting.

There will be trouble for the beginner with air ›ubbles most likely. The best advice to be given vith regard to them is not to worry about the bubbles ınless they interfere seriously with the observation ›f the object. If they do, it will probably be the [uickest plan to make an entirely new slide with nother and similar object. The air bubbles may ›e dealt with by heating the slide upon the mounting-able to such an extent that the balsam is seen to be luid, perhaps bubbling itself. Then comes some lelicate work in pressing the cover-glass very care-ully, until the whole of the air-bubbles have dis-ppeared. In many cases failure will be the lot of he worker in producing the desired result; it is herefore good advice to give, " Make a fresh slide."

CHAPTER IX

ADVENTURES IN MOUNTING

WITHOUT doubt one of the chief interests in connection with the microscope is the preparation of various objects for the lens. There is such a wide field from which to choose, and the results of your expeditions abroad in search of specimens may be made permanent in such a comparatively easy fashion that the interest in this hobby can never die.

Then, unlike most hobbies, when once the first cost of the necessary apparatus has been overcome, it is one of the best possible from the point of view of the pocket. There is, perhaps, little need to stress that many people since the Great War have had to cut down their expenditure in all directions, and particularly upon their hobbies. The cynic will probably point to the greater number of people who now possess a motor, and that boys, who were once content with a push cycle, are now rushing to and fro on motor cycles of various designs, and usually resplendent in some colour scheme which makes them doubly attractive to their owners. But this is just on the surface, and for the one whose position has improved to allow of a motor, there will be a dozen who have to go slowly in their

pleasures. To these then the microscope should appeal, since a really good and full equipment can be purchased new at less cost than the motor cycle, whilst the outlay bears no comparison with that necessary for even a light car.

By no means think that the microscope is an indoor pursuit; whilst a good deal of work must be done at home, the real adventure begins in the field, by the seashore, in the quarry, in the wood, and, indeed, everywhere, with scarcely any limitations such as other hobbies necessarily impose.

All this brings us to further consideration of the securing and mounting of specimens to form a permanent record, which gives great enjoyment for many years.

We have followed already the simpler paths in the art of mounting; let us now look at some of the more intricate jobs which await the novice. Mention has been made of the little pitfalls which await the unwary in mounting specimens in balsam. Before passing on to further details as regards the objects which may be tackled with this medium, let us note a few extra hints which have been given by some of the expert workers anxious to help the amateur.

Mention was made of the simpler kind of mounting with balsam, where the whole process was carried out at one operation; there is another which is recommended to the beginner keen on good work in this direction. Instead of finishing off the mounting without delay, try the plan of first embedding the object in balsam on the cover-glass instead of

the slide, and then put aside (carefully covered up from all dust) for twelve hours. Bring it out again and give the top of the object another coating of balsam—a mere drop will usually suffice for the smallest objects. Now warm a slide carefully and see that there are no air bubbles present before proceeding to seal down in the manner already described. It will be noted that this is really a reversal of the plan by which the object was mounted upon the slide.

It is suggested that there are some objects which are more easily mounted on the cover-glass than upon the slide. The novice is strongly advised to try both methods, *with the same object*, or rather two similar objects, and take note which is the easier form of working. Then he may adopt this as his standard, always remembering that there may be here and there some particular specimen which will be more easily dealt with by the opposite plan to that usually employed.

Apart from the question of which is the better method of the two, it is a good wheeze to have a change in practice at times; it certainly relieves what slight monotony may be found with the work of mounting.

A word of caution may be given here to the beginner. He may think that we stress too much some of the difficulties encountered, and that either the processes mentioned are too tedious, and really not worth while, or that we are exaggerating the difficulties which beset the path of the novice. What it is really intended to convey is that there is no

royal road to success with the microscope and the use of its accessories, and that patience is the greatest asset a fellow can bring to the hobby. Coupled with patience is careful, unhurried working. These are days of rush, and here is a chance to get away from the hurly-burly of the modern world—and a very pleasant way indeed. But it will fail to satisfy unless you are really determined to achieve success, and are disposed to take both time and interest in these varied, yet intensely interesting, adventures.

So much for the general method of mounting, now let us come down to brass tacks, and describe the method adopted with a few of the more usual objects brought to the microscope.

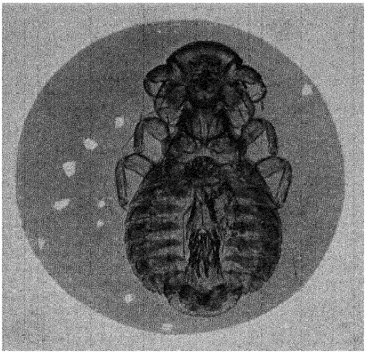
There is the water-flea—a tiny fellow of really most complex make-up—and a splendid specimen for mounting. Failing the water variety you may secure one from the dog, if you have one. Few dogs escape these pests.

The first step after securing the victim is to despatch him without damaging his body in any way. Placed in a methylated spirit bottle his troubles are quickly at an end, and if you are not quite ready to go farther with the work that day, let him remain in the spirit. But supposing you are eager to begin straight away on Master Flea, then lift the body from the methylated spirit bottle and give it several rinsings in changes of water. This gets rid of the spirit. Another item will now be required for your work; if not already in the house buy some caustic potash and make up a solution,

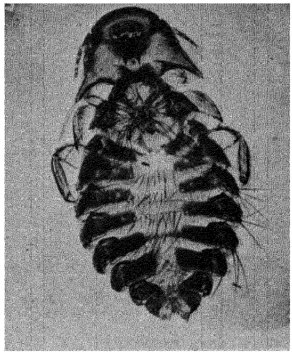
keeping it in a glass-stoppered bottle for ready use. By the way, be sure to label all your bottles carefully, and you should also make a point of keeping them in a cupboard right away from the domestic array of bottles. If, as most likely, you have a fairly large cupboard reserved for your apparatus and slides, allot the top shelf—or the bottom one if more convenient—to your bottles of preparations.

A ten per cent. solution of caustic soda will be needed for the next step. Only a very small quantity will be required for so small an object as a flea. The victim must be immersed in the solution for five hours at least, and it will be better if this period is exceeded rather than lessened. Any small receptacle will do in which to soak the body; some experts recommend the various sizes of receptacles sold for the purpose, but there is nothing to prevent wine glasses which have been rendered *hors de combat* by losing their stems and feet being reserved for such work. Egg cups are both cheap and very handy, but on the whole glass receptacles have an advantage in allowing the objects within to be seen more easily.

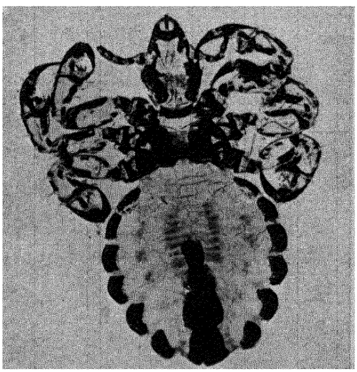
Take the case of the flea, for instance. We want to dissolve all his internal organs, and with the hand glass we can watch how the process is going without touching the body if he is in a superannuated wine-glass. When by judgment, or by sight, this result is deemed to have been achieved, the body must be rinsed several times in clean water to get rid of all traces of the caustic soda. Now comes the next and very delicate stage. Taking a camel-hair brush, the



Parasite of a Peacock



Parasite of a Turkey



Parasite of a Pig

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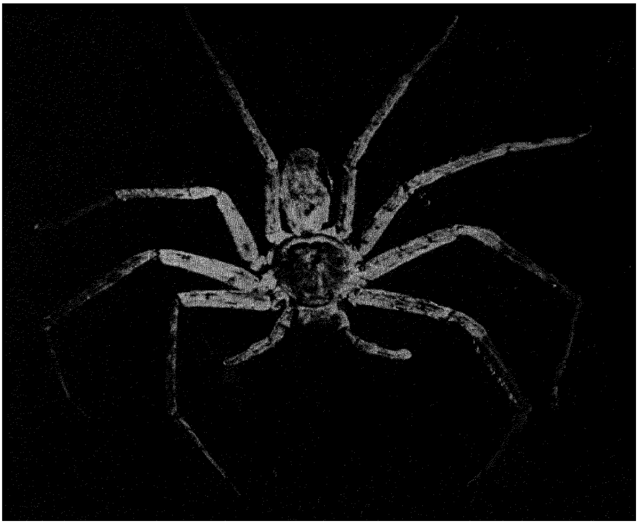
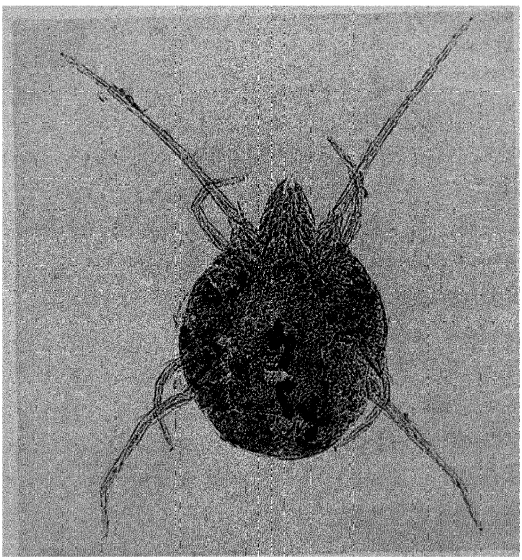


THE COMMON SPIDER



RED SPIDER, THE HOP PEST

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body is subjected to a very gentle series of pressings; this, if carefully done, will free the carcass of the internal organs. It is now necessary to clean the body again to get rid of any traces of these organs which have been dissolved with the caustic soda.

The next step is to place the object—as it has now become—upon a clean slide and spread it to the best advantage; the slip and object are then immersed in methylated spirits. Be sure to cover the receptacle in which the slide and object are immersed as the spirit is fugitive, and some hours of immersion are usually necessary. The spirit has the effect of hardening the body of the flea, but there is still another stage to go through; this is an immersion in turpentine. Again we must give it a few hours as it is most important that the object shall be thoroughly permeated with this spirit, whose effect is also to make the shell of the flea quite transparent. One expert states that he finds it very desirable to introduce still another stage in his treatment of objects of this kind; he recommends that the flea should be soaked in oil of cloves immediately after being taken from the methylated spirit. We are bound to say that although this is desirable, it is not an essential detail, but it does free the object more quickly from the methylated spirit before it is placed in the turpentine solution.

The larger the insect for mounting the longer the first soaking in caustic soda must be. It will also be found quite a good plan, in order to get rid of the internal organs of the larger varieties, to make a

slight incision in the body, preferably at the rear. This may be safely done with one of the needles used for dissection and similar work.

A useful hint is given in many manuals on the next stage of mounting insects which are larger than the flea. It is that the object should be placed between two slides for immersion in the methylated spirit. There would be a danger of injury in tying up the end of the slips. It is therefore recommended that two thin sections of cork sheeting should be inserted at either end between the slides and then they are bound round with tough thread.

It will be obvious that such details as wings and legs of insects will not require the somewhat elaborate treatment indicated above. In the majority of cases the caustic potash bath may be omitted, and the soaking in methylated spirit and afterwards in turpentine can be given forthwith.

We have already noted that there are some sections of slide making which are best done by experts, who have been trained and have the time to undertake what is really very delicate work. This will apply to most microscopists, but there will be the leisured few to whom time is not a thing to be ever fighting. These may desire to go a little way, if not the whole, towards the higher forms of work in mounting specimens.

The first stages towards this are usually by taking various materials particularly those of the vegetable world, and cutting them into the thinnest slices possible. These will need special treatment before their mounting can be successfully undertaken.

We often hear men saying, "What can we do with our safety razor blades?" One answer may be returned by the working microscopist; it is, make them into knives for cutting up thin slices for mounting. With a very little effort a handy fellow may make a holder in which safety razor blades may be firmly held. These holders may be of wood or metal. A friend of the writer's has had a metal holder made which would exactly suit the need of the microscopist. He is not of the confraternity himself, but uses his holder for the purpose of stropping the blades just as the ordinary cut-throat razor is stropped; it may be added, with highly satisfactory results.

The blades slide in quite easily, and are held by the springiness which the maker has imparted to the slotted end of the holder. Any ironmonger should be able to supply such a holder as this should it prove too much for the worker to undertake. Assuming that the holder and blade are ready for work, the best way of using them is to bring a stem or a section of a vegetable to the work table, and then, holding it in one hand, slice in a diagonal direction with the other. By the way, change the blade frequently, and save all your old blades for the express purpose, getting friends to do likewise if your own supply is limited, or again if you do not yet use the razor.

It is advised that vegetable sections should be stained for use with the microscope. The stain not only improves their appearance, but it enables the various details to be followed more easily. It is not, however, possible to proceed at once to the

stain; first the object must be bleached and this must be done thoroughly. It is not a difficult business, and may be done as follows. Take two small jam jars (preferably of glass), and dissolve in one ten ounces of water and two ounces of common or washing soda; in the other, using the same quantity of water, dissolve one ounce of chloride of lime. Mix both solutions well and then pour them together, still keeping the mixtures on the move so that they will now be fully incorporated in one solution. Put the mixture on a shelf and leave for a couple of days; at the end of this time bottle off the clear mixture and throw the deposit away. Some authorities on this subject recommend that the liquid be filtered; others that it will suffice if passed through very fine muslin. In any case it is desirable that none of the suspended material finds its way into your bleaching fluid, as when it comes into contact with the delicate vegetable sections a very uneven result will be found.

The bleaching cannot be rushed, nor must it be left entirely without supervision. Take the sections of vegetable growth which are intended for bleaching and wash them thoroughly in water, then place them in a shallow dish—a porcelain developing dish as used for photography is excellent—and allow to remain for an hour or two. The appearance of the object will tell you when it is finished, but some take very much longer than others. When removed from the bleaching solution the greatest care must be taken in washing thoroughly; treat the objects as if they were photographic negatives or prints; we

all know how much water can be, apparently, wasted upon these, and also the sheer necessity for doing so if results are to be worth while.

Although some workers use iodine extensively as the staining fluid, the more experienced microscopists always advise what is often called the logwood stain, a fluid derived from this wood and known as haematoxylin. This is best bought in solution. The watch glass is a very handy receptacle for the next step, in which distilled water should be used if it can be obtained readily. A little water is poured into the watch glass and then a few drops of the stain is added; the fewer the drops the lighter the stain. It is difficult to lay down any hard and fast rule as to how long the object is to be left immersed; it is really a matter of judgment for the worker, and will depend largely upon the nature of the object. Some materials absorb the stain in about ten minutes; others will require three or four times that period. When it is judged to have received enough stain, wash carefully in distilled water—or if not available with tap water.

To get the best results with your sections the following processes should be followed carefully. First dehydrate in two changes of methylated spirit; then place section in oil of cloves for at least ten minutes, afterwards transferring to turpentine before finally mounting by means of the balsam mixture already described as the best general medium for this work.

Another mounting agent is glycerine jelly, and for botanical specimens many workers will find it

preferable to the balsam, as it has the advantage of being an easier medium with which to work.

We have noted that when using balsam it is absolutely necessary to dehydrate the objects; with the glycerine the opposite is the case, and it will be necessary to give the specimens to be mounted a thorough soaking in water or in something analagous. In point of fact some experts recommend that the beginner should obtain a specially prepared solution from the chemist or microscopic dealer.

The chief difference in working with glycerine lies in the free use of water, and in placing the object in a one to three mixture of glycerine and water before the actual mounting. This is accomplished by placing the object upon a clean slide fresh from the soaking in the mixture mentioned above, and then absorbing, with clean blotting paper, the excess of the solution. Now place some glycerine jelly over the object, light the spirit lamp under the mounting-table, and wait for the jelly to melt. When this is accomplished, take away the lamp, skim off any air bubbles which may have formed, and then lower carefully the cover-glass and press home. Allow the slide to set, giving it about eight hours to do before proceeding to trim off any excess of jelly and the work is now done.

These are the hints necessary for the beginner, but here, as in other hobbies, there is much more to be learned which can come only by actual work with the apparatus provided.

CHAPTER X

SOME COMMON OBJECTS FOR THE MICROSCOPE

ONCE a fellow has come into the possession of a microscope with the adjuncts which have been indicated as necessary for satisfactory work, he will usually find, without much advice, all the necessary objects with which to work. The pond, the seashore, the garden, the quarry—all these are ready to hand, but each will produce something which will be especially suitable for the beginner.

A very attractive series of objects are included under the general name of *Diatoms*, and whilst the average microscopist will be content to take what he can get readily under this heading, it is a fact that some keen workers will spend quite a large sum each year in securing what have been also called "Nature's Jewels."

The microscopists referred to have become so fascinated with these beautiful and really wonderful objects that they have deserted other work to concentrate upon these. Such persons are the specialists, but here we would rather consider the general microscopist. If you consulted the specialist he would tell you that before you could hope to start upon diatoms you would have to purchase very expensive apparatus with an objective which would

be beyond the pocket of the average fellow. If this be true then it is a good reason for making the study of this particular branch an occasional, rather than a regular pursuit. In this way it is possible to use the ordinary microscope, working with half- and quarter-inch powers. Such powers will reveal the great beauties of the general run of diatoms.

A walk along the seashore will give us some good specimens of fossil diatoms. Some will be found floating on the surface, others in a rock pool, and still more attached to seaweed. The beginner will need a word of advice as to the discovery of some of the objects under this heading, thus, some of the objects will be found as a kind of scum on the banks of rivers having brackish water, or, again, at the bottom of ponds, particularly those near the sea where the water is brackish. There are many marshlands round the coast, and these usually possess the small ponds we have in mind. The scum will vary in colour from green to orange, and perhaps it would be better to say "look out for an iron rust scum."

Here are the names of a few of the fossil marine forms found on the seashore, or upon the surface of the water; Melosira, Pinnularia, Surirella, Navicula and Gomphonema. Most of these, under the microscope, will be found to have a shape which is best described as a couple of combs laid teeth to teeth, though the Surirella is rather more like a leaf than anything else.

The Arachnoidiscus Japonicus is a marvellously

beautiful object, resembling, at first sight, an exquisitely designed wheel, whose alternate spokes do not run the full length of rim to hub. Here is a curious fact about this specimen with the long name; it may be found upon stale jam and also upon the fronds of seaweed!

For those who do not have the sea quite handy, and therefore have to hunt their specimens inland, it may be mentioned that there are earths in which diatoms will be found in great profusion.

Most gardeners nowadays use guano; this will furnish some marvellous objects under the microscope, whilst there are also diatomaceous earths. One enthusiastic microscopist has found that certain kinds of tooth-powder, whose base is composed of such earths as that described, will furnish many valuable specimens for examination; he adds, however, that the worker must expect to find some disappointing results at first. He suggests that several kinds of powdered tooth cleansers should be purchased, and samples from each put under the glass, adding that there will be no waste if they fail to give satisfactory results, as they can be used for the purpose for which they were sold. In this way the preparation which contains the greatest number of diatoms will be found, and that can be made the standard tooth-powder, each box serving a double purpose. This microscopist found that one particular brand of tooth-powder showed some surprising results; one box would give practically a blank draw, to use a hunting expression, whilst the next would be full of magnificent specimens.

The new-comer to the microscope will perhaps say, "But will not the specimens so obtained be all much of a muchness?" The answer is that there will rarely, if ever, be found two specimens quite alike. It is really like wandering into a well-stocked flower garden. All the garden is devoted to flowers, but there will be endless choice of kinds, and in those kinds, such, for instance, as pansies, there will be endless variety and markings.

It is quite true that in the case of the Arachnoidiscus there are many varieties with no essential difference; on the other hand, some of the discoverable forms baffle description; it is as if a fairy artist has been at work. Such a form is the A. ornata, which some microscopists claim as the most beautiful of a very beautiful family. Another circular diatom is the Heliopelta. Under the microscope this species has the appearance of the steering wheel of a motor car, but the spaces between the rather wide spokes are filled in by a large number of tiny dots. Another description of this object is that it resembles a convex shield.

It is suggested that diatoms should be examined under low powers as well as high, indeed, some experts claim that the real beauty of the diatom is more pronounced under the low power. The real difference lies in the fact that under low power the markings are not so apparent, but their place is taken by a glowing iridescent colour.

Another series of valuable specimens comes under the general title of Foraminifera. These are really very minute calcareous shells. They have the

advantage of being easily obtained, and also in a great variety of forms. In various parts of the country, and particularly where chalk beds abound, there will be endless scope in obtaining these specimens, and they will be found to be very interesting, and, in most cases, very beautiful. It is advised, however, that the microscopist should obtain a few "spread" slides; these can be purchased at most shops which stock microscopic requisites. The objects on these slides have, as a rule, been dredged from the bed of the ocean, or from rivers, and they thus provide the worker with something which he could not hope to acquire in the ordinary way.

Most of us have to buy a new sponge occasionally, but, departing from the usual procedure of purchasing one from the chemist, go to the paint dealer. This man will usually have in stock a goodly number of sponges, of the commoner class, which are sold to painters for washing down paintwork. No care has been lavished upon these sponges to get rid of the sand, etc., from which the best class sponges have been freed before being put on sale. Even where this has been done there will be a deposit of sand if the sponge is left to soak in a basin. There will be much more sand from the paint dealer's sponge, and it is suggested that, before soaking, the sponge should be cut up into small sections, thus freeing the sand more easily, but also allowing the larger calcareous shells to be come at. After the sponge has been left in soak for, say, twenty-four hours, collect carefully the deposit at the bottom of the basin, and, after drying, examine thoroughly under

the glass. At once it will be seen that there is a good range of specimens of foraminifera, and the best should be picked out for mounting upon a slide, the mounting being done either in the dry cell with a black ground, or, alternatively, simply spread out on a slide and then mounted in balsam.

The seashore is a constant source of specimens of this kind, and the best method of collecting foraminifera is to seek carefully for the whitest sand, usually left in beautiful ripples by the retreating tide. The sand should be taken only in calm weather as, following a storm, there is too much of a mix up to get really satisfactory results. If a spoon is carried along with a bag, or better still a bottle, these sand waves may be scooped up carefully and brought home for examination. As there will be plenty of choice it is well to have the pocket glass constantly in play, and thus select your specimen sand from the sources likely to reveal the best results, the glass will determine when these results have been achieved.

Other objects of fascinating interest are described under the general title of Radiolaria, which, by the way, has nothing to do with Wireless as one youngster suggested when he read the title of a chapter. As he was a wireless rather than a microscopic fan he was quite disappointed. The most beautiful of a very remarkable series of objects are undoubtedly Polycystina. Under the microscope a rich variety of form is found. They are really the flinty shells of minute animals which, in life, float about the surface of the ocean, particularly in the warm waters

of the West Indies. After life they appear to sink to the bottom and form a kind of mud on the bed of the ocean. It is calculated that, in time, the ooze or mud at the bottom of the ocean is lifted above the surface, and then, perhaps in the course of centuries, forms the bed of something resembling sandstone. It is thus possible to get polycystina from land and sea. Some of the best examples of this interesting product of nature have been obtained from sandstone rocks in the Barbadoes, while the famous *Challenger* expedition dredged some very numerous varieties from the ocean bed in that part of the world.

It is probably better to buy slides already prepared of these forms of radiolaria. Under the microscope the tiny shells take various forms, but, in all cases, it will be observed that they are pierced with numerous holes or pores.

Then we come to mineral specimens—which give us a very wide range indeed, and amongst them some very beautiful and surprising objects.

For the new-comer it may be mentioned that, with mineral specimens, it is usual to employ polarized light, and there are some experts who say, very definitely, that good results can only be looked for if a petrological microscope is employed. This is rather a counsel of perfection for the average worker, but he should not thereby be persuaded that the wealth of the mineral work is taboo to him as a result. With patience, a remarkable range of subjects may be examined without polarized light, but it is almost certain that when the beginner has passed his novitiate stage, he will go on to the higher

branches of microscopy and will work with polarized light as indicated elsewhere.

If we take a section of chalk, for instance, and bring it under the lens with a very moderate power, we shall find it of great interest. In the majority of cases it will be found that most of the varieties available for the microscope are made up of the compressed remains of foraminifera.

Bring home chippings from rocks, and try your hand with these. One expert microscopist gives it as his considered opinion that the most fascinating side of microscopy for the beginner lies in visiting stone quarries—both the old worked-out kind and those still in service. He suggests that the collector should take a bag and a hammer on a Saturday afternoon, or some other time when the men are not at work, and complete a thorough examination of the same quarry—if in work—every month. He says that the manager, if approached in a tactful manner, will readily accede to the request of the keen collector. As a rule permission will be given only when the men are away from the quarry, as not only does the presence of a stranger detract from their work, but there is an element of danger to the searcher when blasting operations are on. He might not see the red flag warning him of what was to take place.

Another favourite hunting ground for specimens is the waste bank of a colliery. Fortunately, perhaps, for the microscopist in other ways, he will be at some distance from the nearest pit; seldom do their shafts and chimneys improve the air of a district, and never the appearance. But in the industrial portions of

Britain pits are numerous, and even the fair garden of Kent has been invaded by the towering structures which are necessary for the raising of coal.

The members of field clubs may easily make the journey to the nearest pit, making it a special trip of a rather out-of-the-way kind. Failing this there is the domestic supply. If this is delivered in the shape of large lumps, a very profitable and useful afternoon, especially so far as the servants are concerned, would be spent in breaking up the largest lumps into usable sizes. Such operations would almost certainly result in many fossilized remains being discovered; these should provide a rich storehouse from which the microscopist could draw his spoils.

Another source of much pleasure and profit may be tapped by taking any kind of salts, putting them into solution, and then allowing each kind to crystallise upon a slide. These may be mounted when dry in the manner described elsewhere, and some really beautiful results will be shown. There is nothing more beautiful than the crystal when placed under the lens. If used under polarized light, strangely beautiful colours will be shown, and you have, for your microscope, a series of slides which compete successfully with the emeralds, diamonds, rubies and turquoises worn by a woman possessing a rich heritage of precious stones.

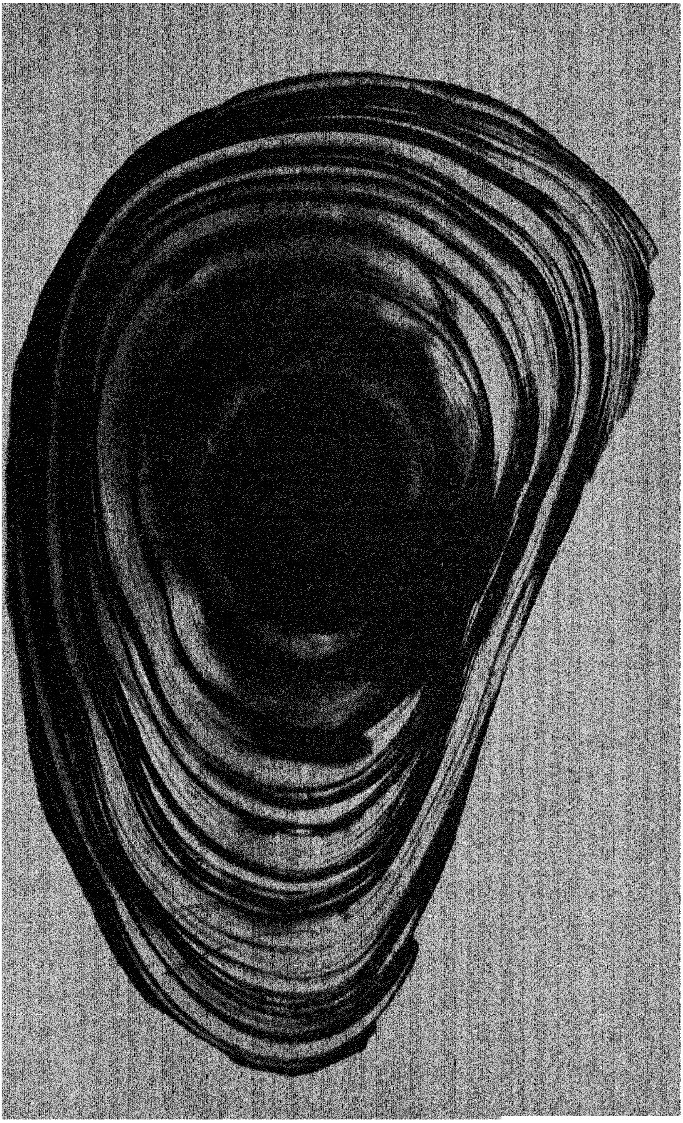
It is not necessary to specify any particular salts in this connection. A visit to a chemist's shop will allow of a rich variety being obtained for a very moderate cost. The beginner may prefer to purchase the salts in solution, and then carry out the mounting

as follows; the solution should be heated and the merest drop should be deposited upon a perfectly clean slide. The cooling down process results in crystallisation, and this is rather fascinating to watch as it takes place. For mounting, the benzol-balsam process is strongly recommended, but it must be added that certain crystals will dissolve during or after mounting. To meet this difficulty either castor oil or copal varnish may be used as the mounting medium.

Microscope dealers have usually on hand a series of prepared slides which contain what are called "fatty acids." These are specially prepared to be melted over the spirit lamp. Gradually the heat must be applied in order that the slide may not be cracked, and if care is exercised, the same slide may be used for many demonstrations. It is in the cooling process that the finest results will appear. It will be seen that various-sized and most beautifully coloured crystals will be thrust out in the cooling process.

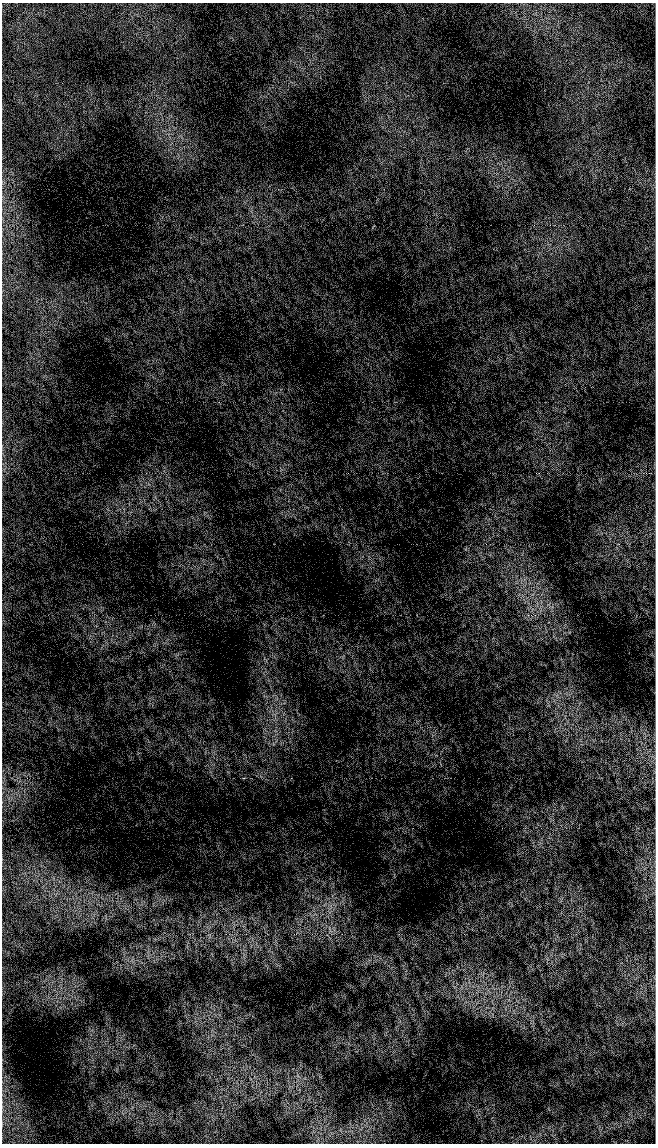
Some microscopic experts recommend very strongly the use of Hippuric Acid crystals for demonstration; this is one of the acids which will not mount satisfactorily in benzol-balsam, and it is suggested that castor oil will be found the best medium.

More easily obtained, and indeed in stock in most households—are such crystals as borax, carbonate of soda, Eno's fruit salt, Kruschen salts, Epsom salts, tartaric acid and similar domestic salts. All these furnish suitable specimens for the lens. Although they may be examined in the form in



AUSTRALIAN WORM PEARL ×13

[*Face page* 102



SLITHER OF A PEARL SHELL SURFACE × 550

Face page 103]

which they are already available, and the variously shaped crystals can be separated upon a slide for more detailed examination, the best results will be obtained if they are treated with heat and the cooling process followed as already indicated.

Sulphate of copper—either by itself or mixed with magnesia—may be added to the list already given.

The insect pests of the garden are favourite subjects, too, and the gardener will welcome your forays in search of wire-worms, slugs, snails and particularly the grub of the daddy-long-legs, which is so toothsome a morsel for the thrush, but so desperate a fellow at the root of a favourite flower.

In microscopy the whole world offers itself, and the best advice is really to go in and help yourself. We have tried to indicate some of the more easily obtainable specimens, and how they may be brought under the objective.

CHAPTER XI

SOME COMMON OBJECTS FOR THE MICROSCOPE

ONCE a fellow has come into the possession of a microscope with the adjuncts which have been indicated as necessary for satisfactory work, he will usually find, without much advice, all the necessary objects with which to work. The pond, the seashore, the garden, the quarry—all these are ready to hand, but each will produce something which will be especially suitable for the beginner.

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As we proceed with our study of objects under the microscope, we shall be driven to the conclusion that every vegetable has its beginning in a simple cell. The tree, for instance, is a mass of small cells, whether we examine the bark, the hard wood, of the trunk, the softer wood of the new branches, the leaves, the pith, the flowers, or again the small hairs, which will be found on most trees.

In the summer various kinds of fruit will lend themselves as objects for the microscope, and the more they are dissected and examined, the greater are the wonders they reveal. Thinking for a moment of fruit, take the strawberry, which is an excellent fruit for the microscope, as well as for the palate. With a sharp knife cut away a piece of the outer skin of the fruit, and from the other side a rather deeper portion also containing a section of the outer skin. Place these two sections upon a slide and bring it under the power of the lens, using approximately 200 diameters. The cells of the strawberry will be plainly discernible, and, as a rule, they will appear to be spherical. In some cases, however, where the fruit may have been under some pressure, the globular form may have been lost.

Having discovered the cell, let us pause for a moment to examine it and find out exactly what it is. It may be described as a close sac, formed from a substance which we know very well in commercial life, that is cellulose. There are many forms of cellulose, and it is of interest to note the remarkable

change of opinion as regards what we may call its commercial use. Before the War cellulose was prohibited in jam, though at one time it was freely used. During the War, however, its food value was recognized, and it was permitted to include it again in the make-up of this article of food.

The cellulose of the strawberry cells contains certain semi-fluid contents so long as the cell remains alive. By means of the microscope we shall be able to explore the cell and right in its interior may almost certainly discover a small dark spot; this is termed the nucleus. Very little is known of this nucleus, and scientists are still uncertain as to its exact use. The best opinion inclines to the view that it is the real thing that matters in the cell, inasmuch as it is intimately connected with both the growth and the reproduction of the cell.

We may pass from the strawberry to an entirely different kind of vegetable growth. Secure a common stinging nettle, having taken the precaution of putting on a glove. The first examination should be made with the hand-glass, which will show very clearly that the stinging hairs are scattered over the leaves, as well as the stem. They are curious and rather wonderful things, these hairs, and it will be necessary to put them under the microscope if we are anxious to examine them further. A sharp knife is necessary to cut away a fine section of the skin of the stem, taking care that we secure a portion with the hairs still attached.

This skin must be placed between two glass slips, and then carefully examined with the one-inch objective. It may need a little manipulation to see the wonderful nature of these hairs, but patience will be rewarded, and at least we shall make out quite easily what appears like a remarkably fine needle. It is not, however, like the steel needle that we usually think of, because it is clearly channelled through its centre, and it has a curiously rough appearance. This appearance has well been described as flinty. When the hair is still further examined it will be found to have at its apex a very small ball of flint, which closes the tube.

Remember how badly the nettle may sting; it is exceedingly interesting to find out why this is possible, and this the microscope will allow us to do. At the base of the tube we have recently discovered there is a poison sac which holds some irritating fluid. It is one of the wonders of the nettle that it should be able to force this fluid into the human skin via the centre of the needle. What really happens is that when we grasp, or even touch the stinging hairs of the nettle, the small ball already mentioned is broken away, and even the merest touch is sufficient to cause the fluid to be forced up the channel into our skin. The skin, by the way, has already been penetrated by the sharp needle. An experiment may now be carried out to show the remarkable flintiness of the needle; this may be undertaken quite apart from the microscope.

Assuming that a piece of platinum is available, or some other metal which is quite thin, and yet will stand the heat of the spirit lamp, the hairs of the nettle may be placed upon it and then brought over the flame of the lamp. After the heat has destroyed the organic matter, it will be seen that the needle is much as it was.

Leaves will supply a long list of objects for the microscope, and it will be impossible here to give more than a few general hints upon how they may be brought under the lens. Take the buttercup leaf, for instance, which, fortunately, is so readily available that there will be few microscopists who will not be able to secure this specimen. The external skin of the buttercup leaf may be stripped off with care, and the cell walls will be noted. The leaf shares with others abundant spots of chlorophyll, giving it its rich colouring. It is well known that plants must breathe, and that to enable them to do so, they have mouths. Scientists call them Stomato. If the external skin of the buttercup leaf is examined, it will be seen that it has been covering the Stomato of the under-surface.

Other good examples of leaves for the microscope are those taken from the common iris. These will show the Stomato and the elongated cells.

Without the microscope there are many leaves and plants which show quite plainly some beautiful veins or lines. Under the microscope these may be more closely examined, and will reveal some really beautiful structures.

Mention has been made of the hairs of the nettle,

and most of us, at different times, have experienced to the full the very irritating methods of attack, but apart from the hairs of the nettle, there is a vast range of study in connection with those of other plants. Some of them are so minute that only with the aid of the microscope can they be seen at all. Few people, for instance, would imagine that the leaf of the lavender was covered with hair, but it is this fact which gives it that very beautiful bloom-like appearance. Under the microscope it will be seen that the hairs of the lavender leaf grow into an upright stem throwing out horizontal branches in practically every direction.

If we examine it more closely, we shall see that, sheltered by these branches, and between every two upright hairs, there are some curious appendages. These are the reservoirs which contain the glorious perfume which everyone knows. It would seem that nature has placed these reservoirs under the spreading branches in order that they may be thoroughly sheltered. Further examination will show that the reservoirs, in the shape of globular cells, are very numerous, and they seem to gleam like beautiful, tiny pearls amongst the hair branches which shelter them. If the leaf is turned over it will be found that the reservoirs are far more numerous on the under side.

Another common object for the microscope is that wonderful flower, when gone to seed, of the dandelion. Care will have to be taken in bringing it under examination, since once detached from the stem, the seeds are quickly blown away. Under the lens, it

will be seen that a single hair is composed of two layers of elongated cells which lie close against each other. The whole of the dandelion top is worthy of the closest examination, and we shall be able to see how the seeds are carried for miles by means of the tiny parachutes which serve this purpose.

CHAPTER XII

FOUND ON THE SEASHORE

THE SPONGE, right from the earliest days, until at least the middle of the eighteenth century, was always a centre of dispute amongst students of the products of the ocean. Some said it was a plant growth, others that it was formed by some marine insect, probably a worm. Still another faction contended that sponges were animals, and that they lived upon the sea water, and used the various cavities to draw in their nourishment, and to expel anything that was not required. Later came the aid of the microscope for the examination of the sponge. Several very curious results were obtained immediately, and it was possible to split up a cell and analyze completely its constituents.

The scientists who had made the sponge a particular study under the microscope, found that it consisted of three layers, the first being a rather delicate outer skin; then came a middle layer, in which was found a considerable amount of lime, which seemed to be used to form the skeleton of the sponge, and then came the inner layer of cells. The microscope showed that the outer skin, like that of a human being, possessed very small pores. It appeared at first that the water was drawn through these pores

into a central cavity, and that the cells of the inner layer were alive, also that they seized upon the tiny food particles which came to them, and actually swallowed them. Then it would seem that the nutritive matter was extracted as it flowed along from cell to cell, and when all the goodness, as it were, had been obtained, then the waste products were thrown off through one of the large openings in the sponge.

Further, the microscope revealed that the spicules of sponges had a most remarkable range of form. Under examination it was seen that the simplest of them resembled a needle with a double point; that is to say, a point at either end. There were other forms which showed a most amazing number of objects; there were crosses, wheels, stars, many like pins, more still like nails, and a few, in each section, which resembled anchors and grapnels. In addition, the microscope showed that there were any number of mixtures of these figures; thus, the pin would be crossed with a nail, the steel and the grapnel would be seen to be linked together.

There are two kinds of sponges, one of which is little known, this is the fresh-water sponge, which has a skeleton formed from spicules of flint, these resembling the needles pointed at both ends already referred to. Wherever the fresh-water sponge is found, it will be noticed that the water there is constantly renewed. The fresh-water sponge favours the banks of rivers, and it is often found upon floating timber. Even in docks and canals, in which the water is frequently changed, it will thrive exceedingly.

The microscope has shown very clearly how there is a constant inflow and outflow of water through the fresh-water sponge.

When experiments were conducted, some time ago, the microscopist determined to add some colouring matter to the water to determine definitely whether the theory that the sponge took in and expelled water continuously was correct; it was at once seen, by use of the powdered carmine, that what had been suspected was clearly a fact. The fresh-water sponge has one very remarkable quality; it is that it is really indestructible. No matter how much it is sub-divided, each of the divisions will carry on quite an independent existence; moreover, if they are allowed to remain in close proximity to each other, they will quickly reunite and become one organism again.

Those who have studied sponges, especially under the microscope, have discovered several rather remarkable features, thus, they may be reproduced by budding, much as the gardener will bud one tree upon another. There are also male and female elements, and these again under the microscope are clearly to be made out. One theory has been advanced that the fresh-water sponge will produce winter eggs, and that these will produce in turn male and female forms. It is possible, though it is not certain, that this is one method by which the fresh-water sponge perpetuates its race. It is thought that the eggs are sometimes scattered by the wind, and in this way they come to the water where they are light enough to float until such time as they come

in contact with a wall or piece of timber to which they can adhere, and then begin to grow into a sponge.

It is not generally known, perhaps, that the sea-water sponge is quite common all around our British coast line; the microscopist will look for them amongst the seaweed, and the commoner kind, which are sac-like, will be found quite readily. Another one is known as the Mermaid's Gloves; this has a flinty skeleton, and it is found in considerable quantities on the south coast, particularly around Eastbourne.

Still another common form of British sponge is called the Crumb-of-Bread; this is usually found upon rocks, and particularly on the large weeds which cover the rocks. A smaller variety is known as the Boring sponge, which will be found with oyster and scallop shells. No one visiting the seaside should fail to collect some of these remarkable examples of nature's work. There is one piece of advice that it is wise to give; quite a number of people have taken them home, and in many cases have added them to their salt-water aquarium. It is unwise to do so; if they are taken home at all, let it be for use with the microscope. The sponges, away from their native element, have a very short life, and the contents of many well-stocked aquariums have been entirely spoiled through the corruption caused by the death of the sponge.

Amongst other objects found on the seashore an arresting one is certainly the starfish. Of themselves it may be said at once that they are useless for

the microscope, but it will be found possible to obtain them in their early stages and submit them to careful examination. Few things undergo so many changes as the starfish; in their primitive state, the starfish are developed from pure larval forms, and it is the changes which they undergo from this form that make them of special interest to the student of objects found on the seashore.

It is necessary to keep a close look out upon the rock pools, and to try to find specimens of the starfish in various forms and stages of its growing up. Unlike the sponge, the baby starfish may be taken home to the aquarium, and they will actually grow up to maturity, and they have been known to breed in captivity. In order that this shall be accomplished it is necessary to feed the starfish with fish or small pieces of meat. On several occasions eggs have been secured, and starlets have been obtained from them and successfully reared. The larva of the starlet is first observed as a free swimming creature, and it passes through several interesting stages, until some very slender arms are developed, these wave about and appear to serve the creatures as their method of locomotion; in addition, the arms bring some tiny particles suspended in the sea into their mouths. The next stage is where the disk begins to form at the rear of the tiny body; now the arms appear to be lost; really they are absorbed, and it has been suggested that the growing starfish actually feeds upon the substance which formed what we may call its limbs.

Few things allow of such interesting study as the starfish in its evolution from larva upwards. In order that the evolution may be followed quite easily, it is suggested that some of the eggs be placed in water in test tubes; these should not be filled, but sufficient water placed in them to keep them floating in an upright position. In this manner the development of the starfish may be watched closely from day to day, and, under the magnifying lens, some remarkable changes will be seen.

A close relative of the starfish is the sea-urchin; they possess some remarkable organs, which may be best described as tiny forceps. In the starfish the forceps have two jaws, but in the sea-urchin there are three, and they are apparently used to help the creatures to climb; With these strange natural forceps they can catch hold of a piece of floating wood and raise themselves quite easily. As a rule it is easier to obtain the sea-urchin, and mount it upon a slide for use with the microscope, becoming, in fact, one of the permanent objects of an amateur's collection. It is, however, better to observe them whilst alive, if possible, and here the hand-lens will be extremely useful, especially when utilised in conjunction with an aquarium, though here, again, care will have to be taken to keep the sea-urchin under focus.

Another plan is to use a pair of forceps and examine the creature in a watch glass.

A visit to the seashore with a bottle and a net will provide endless occupation for the microscopist It is better really to bring them home, and there deal

with the numerous specimens at leisure. Amongst them will be wood- and water-lice, shrimps, water-fleas, barnacles and diving spiders, and various kinds of insect larvæ. It is better to use a dipping-tube with the store-bottle, and having dropped the contents of the dipping-tube into a watch glass, the curious and minute insects may be transferred to a live-box for work under the microscope.

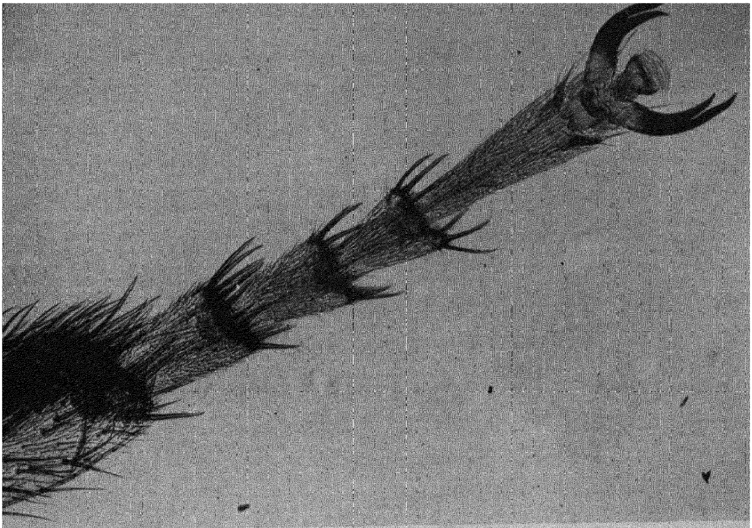
The water-flea will be found an exceptionally interesting specimen; almost certainly the first one to be under the microscope will prove to be a female, because they largely outnumber the males; in addition, they are considerably bigger. They lay two kinds of eggs, known as winter and summer eggs. Those laid in the winter are fairly large, and have a particularly thick shell. It is supposed that this is given because the eggs remain for a considerable period at the bottom of dried-up ponds. Unless fertilised the eggs will not hatch out; when they do, they always produce the larger flea, viz., the female. Curiously, the summer egg is not only smaller, but very much thinner in the shell. The surprising fact about this is that they develop without fertilization, and their product is invariably a male flea.

Under the microscope the water-flea shows itself as consisting of two very distinct portions. The head, which has a remarkably free motion from the body, appears to be prolonged to a point, resembling somewhat the beak of a bird. The body is comprised of two valves, which seem to be enclosed in a ruddy-coloured shell. This shell is singularly clear

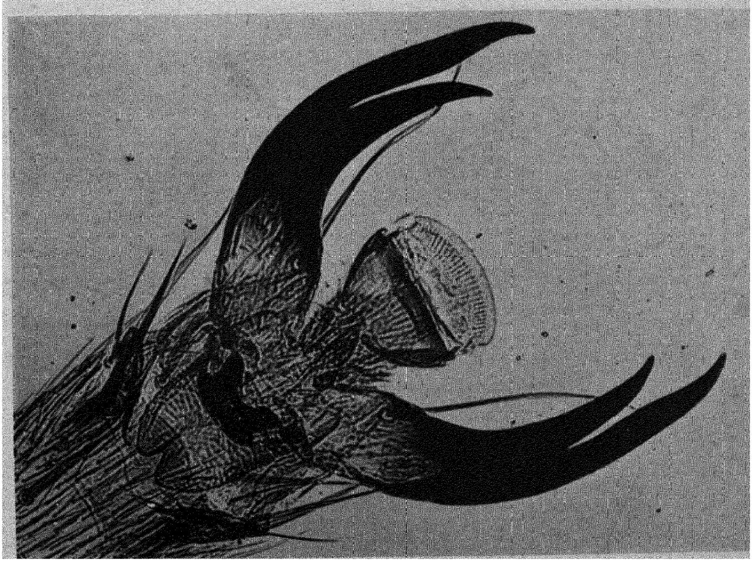
and smooth, but there are some fine lines upon it which could never be detected save through the aid of the microscope. In addition, the shell is quite transparent, so that the whole of the working portions of that small body are apparent to the observer. A remarkable fact about the water-flea is that in its infancy it had two eyes; as it grows to maturity they come together to form a single one. But these have twenty crystalline lenses, which seem to be placed very regularly round a mass of black pigment, which is quite in their centre.

The microscope in this case allows us to watch very closely what happens with the digestive organs of a creature of this description. It is a wonderful proceeding, and without doubt nature has provided here in miniature what happens in greater insects and animals.

Another remarkable feature which the microscope will reveal is the presence of two bunches of eyes. They are placed in such a position that they can remain there out of the way until they are quite hatched. Look now for the feet of this curious little beast; there are no fewer than five pairs. Perhaps it is hardly fair to call them feet, because they are certainly not used as we use them. Not for a moment are they still, and we must conclude that their main objective is the production of a constant flow of water through the valves, which undoubtedly helps the water-flea to breathe. But these curious little feet have another use, the microscope may not reveal this, but it is nevertheless a fact that the feet collect very minute particles from



BEE'S LEG ×25



BEE'S FOOT ×75

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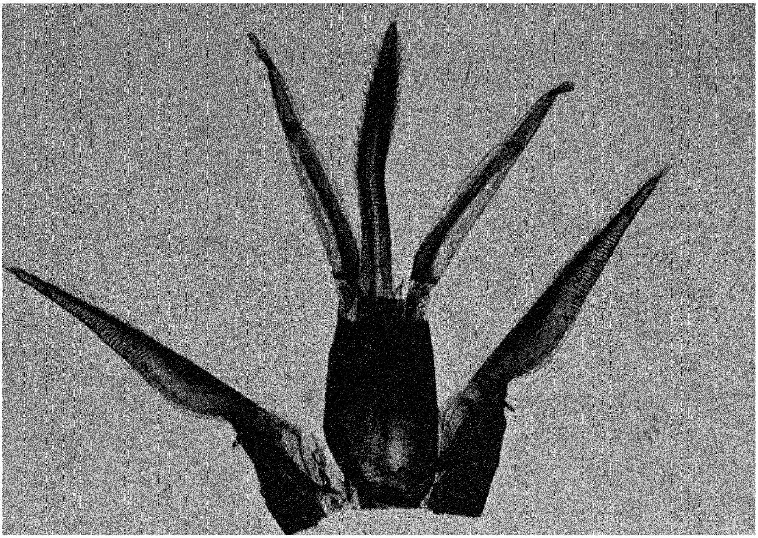
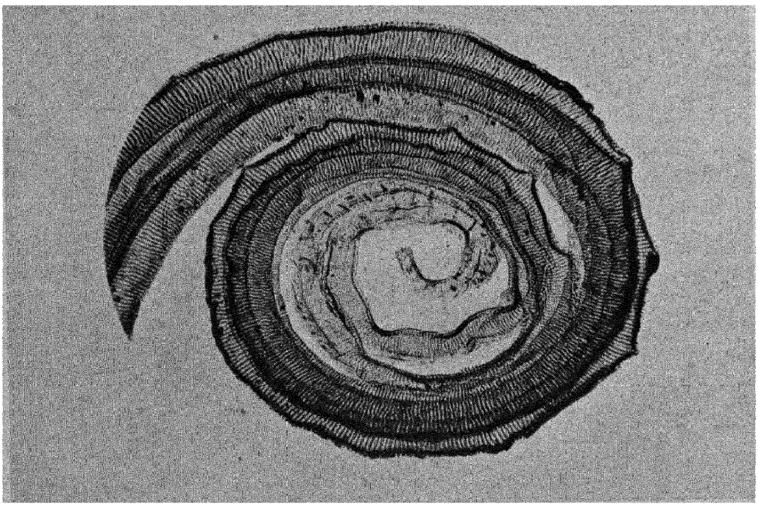


TONGUE OF HIVE BEE × 15



TONGUE OF BUTTERFLY

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the water in which they are working, and what is still more remarkable, the feet form them into tiny pellets, which are then fed to the mandibles.

Leaving the feet of this curious little creature, we turn to the examination of the head. At once we notice two pairs of appendages, which are known as the superior and the inferior antennæ; one set of these are used for propelling the flea through the water.

There is a very small creature resembling a tiny crayfish; this is often called the Cyclops. It belongs to the Crustacean family, and, if watched in its progression through the water, it will be noticed that it does not proceed as most creatures do; instead, we might say that the Cyclops shoots through the water in a series of sharp spurts. It has a single eye which is placed in the centre of the head. With the microscope, observe closely the head, which appears to be flattened out in a rather remarkable fashion. The tail seems to divide into two sections, and surrounding the whole of the body are a series of curious plant-like growths. The body, by the way, if placed upon end, resembles very much one of the old-fashioned pegtops which were so universal a toy in years gone by.

The Cyclops may be kept in an aquarium, and if a specimen can be placed in a test tube, as mentioned earlier in connection with the starlet, the evolution of the egg to the creature may be watched at leisure. Some experimenters have detached the egg box from a Cyclops, and have then watched the young hatch out in a glass, or even in the aquarium.

Still following our investigations of the rock pools, which for preference should be as near the low-water mark as possible, a whole host of creatures await examination. Look out for the eggs of the common cuttle fish; too frequently, plentiful as they are, they will be passed, unless one is out for specimens. In appearance they resemble black grapes, and are almost invariably attached to a piece of seaweed, or even a floating log, the attachment being a kind of flexible stalk. Fishermen call them sea-grapes, and if a few can be carried home in a bottle containing sea water, it is not a difficult matter to hatch out the young. In any case, one or more of the eggs should be taken from the bulk and utilised, by the dissecting needles, for the microscope. It will be necessary, in connection with the dissecting needles, to take away the covering so that the interior may be examined quite easily.

It is necessary to be careful in the use of the needles, because, quite easily, the fluid which fills the egg may escape, and the work undertaken will have been valueless. Try to do with the egg what you would with a grape, taking at least as much care as you would with one fully ripe. At once the baby cuttle fish will be seen there, if it is only half developed, the head and eyes will be observed by means of the microscope. As with so many creatures, it will be apparent at once that they are out of all proportion to the rest of the body; the proportion, of course, becomes normal when the egg is hatched out and real growth begins in the outside world.

Now comes a most marvellous result if sufficient care can be taken in the dissection of this rather delicate item; by the way, whatever is done will have to be accomplished under water. If it is possible to get almost to what we might call the stone of the grape, meaning, in this instance, the cuttle fish egg, it will follow that the tiny creature will be released, and as soon as this takes place, off it goes swimming for all the world as if it were a grown up. It is quite clear to the observer that the tiny creature can see, and if there are any obstacles in its path it will swim round them. Now strive to take it out of the water, if possible into your hand. In nine cases out of ten the baby cuttle fish will send out a dark-coloured fluid, something like ink, in which it will try to escape; this is nature's protection for the little creature.

Look out also on the seashore for a specimen of the sea-slug, some of which are wonderfully coloured. Choose the best coloured specimen you can find. If you intend keeping one of these creatures you must see to it that it has a place to itself, for it is well known as a flesh eater; if kept in an aquarium it will almost certainly prey upon some of the occupants. A naturalist who took several sea-slugs home, knowing of their propensity to feed on other dwellers in the aquarium, put them by themselves. Observing them the next day, he found that their numbers were less, and as he watched he saw the larger attack the smaller, whilst the smaller defended themselves as well as they could. But the result was a foregone conclusion; the larger ate the smaller,

and that accounted for the decrease which had taken place during the night.

It may be that the sea-slug which you bring home is rather too unwieldy for use with the usual kind of microscope possessed by the amateur; in this case, it is desirable not to trouble with the slug, but to concentrate upon some of the egg-mass, which may be obtained quite easily. A remarkable fact about the sea-slug is that the sexes are combined in a single individual. For this reason you will watch for some of the spawn of the sea-slug, which will be found in various parts of the seashore: as a rule seaweed or rocks will reveal some of it. Unless the searcher knows what to look for, he or she may search in vain.

If, however, a flat stone is found in the vicinity of sea-slugs, it is almost certain to have been used by them for depositing their spawn. This, when it leaves the slug, is very much like gum, but quickly it becomes hardened when it comes in contact with the sea water, and it would appear that the creatures endeavour to coil it round and round in such a way that it resembles the top of a very small cabbage. The naturalist calls it an egg-ribbon, and the best plan is to cut a section away from a coil when found, and carry it home, keeping it in a wine-glass filled with sea water.

The egg-ribbon may be examined from day to day, and the gradual evolution will then be seen. Some of the stages which will be noted are the gradual breaking up of the egg-ribbon into minute sections; upon these the microscope must be

brought to bear. It will be noticed that the eggs have reached a larval stage. There is still a kind of transparent shell through which the development can be watched. Eyes and tentacles are formed, and once the shell has fallen away, the baby sea-slug begins to crawl about in exactly the same way as his parent.

CHAPTER XIII

SOME MORE OBJECTS FROM THE SEASHORE

THE SHELL-BINDER possesses a house which is very like the case of a caddis-fly; as a rule, however, it is of considerably greater size. The tube, which we have called the house, is easily broken, but it would appear that the worm has been endowed with a means of making quick repairs to it. From observation it has been found that unless the worm itself is damaged it will at once begin to make good the harm done to its house.

Whilst most of the worms are attached more or less permanently to seaweed or rocks, the shell-binder is something of a traveller. What causes him to travel no one really knows, but those who have kept them in an aquarium have seen them come out of their tubes, and move along.

Gosse, the famous naturalist, has recorded of one of these curious worms that, "The body hung down, and the tentacles some fifty or sixty in number, were spread out on each side, and above, on the surface of the glass, adhering to it evidently, and alternatively elongated and contracted, with an impatient, writhing, twisting action, the result of which was to crawl, not very slowly either, up the glass." Gosse records later on in his story of the

shell-binder that "It was interesting to see how much at home the little worm was at this performance; I doubt not, he had enjoyed the fresh air in the same manner, many a time."

The shell-binder, it will be seen, is essentially worth while examining under the microscope, and much of the enjoyment of magnification and examination will lie, first in obtaining these specimens, secondly, in keeping them in conditions as natural as possible, thirdly, in placing them under the lens.

In days gone by, the leech was particularly well known to small boys who looked into chemists' windows, first to observe the curious bottles containing coloured liquid, which seemed to proclaim by their number the efficiency of the chemist, and more particularly, to watch the leeches climbing up and down the glass-topped jars, in which they were kept. It is one of the changes in medical practice, that the leech has gone out of business, or practically so. It is not necessary, however, to go to the chemist to produce one for the microscope, as leeches are quite common in rock-pools and upon the seashore generally. Even more so, are types of leeches more common in ponds.

The Clepsine is found in practically every pond, and it is especially interesting to the naturalist. It is possible to capture a specimen and to find it carrying its young about, attached to the under-portion of the creature. Under the microscope, the mouth and the sucker at the tail, which enables them to fix themselves to practically any surface, will be of special interest.

There are many forms of leeches, especially of the smaller variety, who appear to be parasitic upon fish; sometimes it may be possible to secure a small fish and examine it and its parasite. At the same time, under the microscope, it may be possible to see how far the leech is detrimental to the fish.

The Marine Polyzoa are fairly abundant, and they are made up of a tremendous number of species. The largest group known is the Lip-mouthed Polyzoa; here the chambers are horny, and appear to be completed with a kind of hinged shutter, which is operated by muscles. These shutters apparently open outwards to allow the Polypide to escape, and immediately it has gone, the shutter closes.

Another group is known as the Round-mouthed Polyzoa, and these have long tubular chambers which have round openings, not protected by the usual valve. They will be found on weeds and stones, and also upon shells, and they are discovered in incrusting masses. Another group is known as the Comb-mouthed Polyzoa: instead of a shutter these have a row of bristles as a covering to the opening of the chamber. Still another of the Polyzoa family is known as the Snake's-head Coralline; it is extremely common in Britain, and will be found on the smaller kind of red seaweed. The visitor to the seashore, will find the Snake's-head Coralline in very great quantities upon the west and more southerly coasts of Britain, and although it is also found farther north, it is less and less frequent. The name Snake's-head is especially suitable to this strange creature, as, under the microscope, it closely

resembles the snake in the attitude of striking; moreover, the upright part of the creature is closely ringed, whilst a swelling which makes the Snake's-head is marked with a series of tiny dots. The Snake's-head must come out now and then for food, and possibly for air. It is said that, if a powerful magnifier is carried to its native haunts, it may be observed in all its curious beauty; it is essential, however, that a section should be brought home to be placed under the microscope.

Another coralline is known as the Bird's-head, this name is given to several forms, because there is a resemblance to a bird's head, just as in the type described above, there is the resemblance to that of a snake.

A very remarkable experiment was carried out by Darwin, when he was making his historical voyage upon the *Beagle*. He came across some Polyzoa off the coast of South America; observing that the head resembled somewhat that of a vulture, he cut off some of them, and discovered, to his surprise, that the lower part of the beak was still capable of opening and closing; but the most remarkable factor was that, when Darwin touched them with a needle, the beak invariably seized, and held upon the point so firmly that the whole branch might be shaken when trying to withdraw it.

There are many opinions offered as to the real work that the jaws of the Polyzoa are intended to do; some believe that they are for the usual purpose of feeding the Polyzoa, whilst others are inclined to the view that they are utilized to scare away various

visitors, who are not welcome to the creature. Certainly it has been observed that the jaws are continually snapping, and there have been cases where small creatures have been found firmly gripped in the jaws of the Polyzoa.

These creatures will be found an endless source of interest to the microscopist, and should he wish to go further in his study of them, he is strongly advised to obtain some standard work upon these creatures.

The Sea-mat, more properly, the Broad-leaved-Horn-wrack, is very plentiful upon the seashore; as a rule that which is found will be dead, often it is discovered in considerable quantities above high-water mark, and in some districts it is used as manure for fields.

The microscopist is advised to look out for a piece which has been cast up, particularly after rough weather; he is almost certain to find a live specimen, and if this is brought home it will prove of great interest under the lens. Upon the broad fronds of the Sea-mat will be found fairly large colonies of various insects; one of the best known is the Creeping Coralline, these may be identified by their dark lines. Another colony found on the Sea-mat is the Bowerbankia, these are very minute creatures, and they will not be seen properly without the aid of the lens. By all means bring a section of living Sea-mat to the microscope, for there is no knowing what wonders may be revealed from an apparently very ordinary piece of seaweed.

The Creeping Coralline is especially interesting, particularly for the novice. With the microscope it

will prove a source of great interest; it will be found in various forms, but the colonies are nearly always rooted by a disc, and under the microscope it will have the appearance of clinging to the Sea-mat by curious little hooks, which have been well likened to those used with the grapnel.

The Round-mouthed Polyzoa is possibly the simplest of all the family; the chambers of this class are always tubular. There are two distinct divisions of the Round-mouthed Polyzoa, and they are distinguished by the fact that in one case they resemble plant-like growth, and will be found adhering to weeds, shells, and stones, whilst the other form incrustations on various surfaces. In both cases the microscope will reveal some very beautiful details, and amongst the many objects which may be brought from the seashore, there are probably none more worth while than these. They have been well described as resembling very beautiful white flowers, and as a rule, it is possible to examine easily the white tufts into which they are formed, because they are usually found upon the red seaweed.

On this kind there is a kind of delicate lace-work of the type which is known as the incrusting variety, and, by means of the lens, their full beauties will be appreciated. Some of the varieties remind one very much of the coral branches, and these are quite frequently met with, especially upon our south-west coast. The best time to look for them, and to obtain the most beautiful specimens, is immediately after a storm at sea. The waves bring remarkable specimens of flotsam and jetsam to the searcher, but amongst

all of it, nothing more beautiful will be found than the Tufted Ivory Coralline.

Another type is known as the Stag's-horn Coralline; its name was given by Gosse, and it seems a very appropriate one, in view of the branching growth. To Gosse there was another reason for calling it by the name he chose; he observed that not only was the colour similar to that of the young horn of the stag, but he noticed that it had a short, dense pile, which is also analagous to that of the young horn of the hart.

The average person would pass the Stag's-horn Coralline with perhaps a single glance; it is certainly not a very attractive object, but brought to the microscope it is a really wonderful piece of nature's handiwork. It is necessary to snip off a portion and bring home, and when placed under the lens, the full beauty of it will then be revealed. There are many other kinds of Coralline, such as the Grape variety, whilst another is known as the Dodder Coralline; these two follow very closely the Bowerbankia, and, with the rest, they are well worth bringing to the microscope.

As already mentioned, the microscopist who gets really interested in this phase of the growths found on the seashore, it is strongly recommended that he should obtain a work dealing more fully than it is possible to do so here with a very fascinating subject.

CHAPTER XIV

MAKING A MICRO-AQUARIUM

IT WOULD be useless collecting so many interesting objects alive and dead from the seashore, unless they can be kept for attention as and when required. There is only one thing for it, and that is to provide an aquarium, which must have a fairly constant renewal of sea-water. The difficulties of a sea-water aquarium are so great, that, unless the microscopist lives by the seaside, he must be content to have a fresh-water aquarium.

The very name aquarium may frighten the person whose pocket is not very deep; perhaps he or she has been to the Zoo, seen there those remarkable aquaria and then thought that something like those is intended; far from it; what we have to propose may be the simplest and inexpensive of fittings.

To anyone at all handy, the question of making the aquarium at home should be considered; it is not at all a difficult task. The first point for consideration for the home-made aquarium is its size, and this must really depend upon what space can be allotted to it, and whether it is to be placed indoors or out of doors. Doubtless the best place for an aquarium is the conservatory or a greenhouse, but such an annexe to the average residence is not always

available. To take a reasonably good size for practical purposes, we should have a length of four feet, and a width of two feet, with a depth of three feet. The framework may consist of wood or iron, but it is strongly recommended that the latter shall be chosen, for wood is bound to produce a leaking joint sooner or later, owing to its gradual rotting. At once the amateur will say: "This is all very well, but how can I make an iron frame for the aquarium? Wood is fairly simple, because I can make a picture frame, and have the usual tools." Actually, the iron frame is made by the blacksmith from angle iron; it will prove no difficulty at all if you give him the exact dimensions, and when the frame is delivered to you more than half the work is done already, and it should cost only a few shillings.

The next question to be faced is how the bottom and sides shall be filled. For a micro-aquarium it is better to have all the sides of glass, although for other containers it is usually recommended that one side, at least, should be dark, in order not to be too trying for the inhabitants. But as the objects in the aquarium have got to be studied through the microscope at times, it is very desirable that glass of reasonable thickness should be used for the two sides and the two ends. The bottom may be of glass as well, but it may prove more suitable to obtain a piece of slate or similar material. The next item required is a good supply of putty, and this should be well worked up so that it is perfectly pliable, and then placed in the angle portion of the iron frame. The glass sides and ends are then fixed,

the bottom, of course, being placed in first of all. It is very essential that there shall be no leaking joint, and it is a good plan to fill the aquarium with water, and leave it for a full week, noting whether there is any sign of dampness underneath or at the sides.

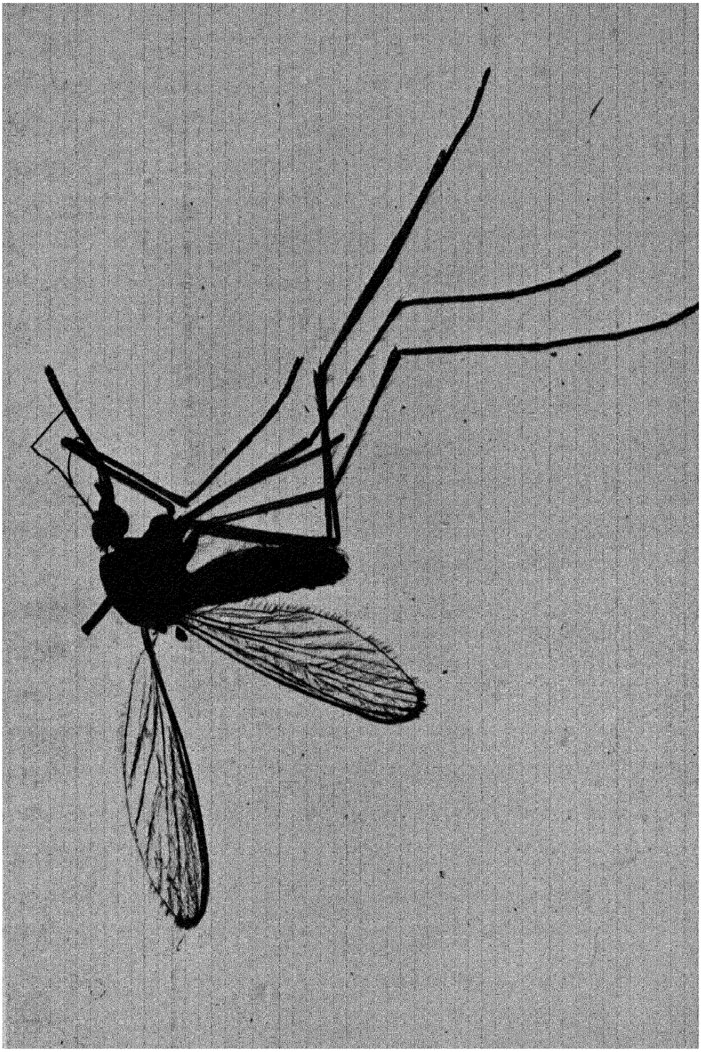
To preserve the iron frame, it is essential that it should either be varnished or painted, but this should never be done until it has been ascertained, beyond all doubt, that the joints are absolutely tight. Again, after painting, the aquarium should be filled with water and left for as long a period as possible, say another week; this should get rid of any oiliness from the paint, which would certainly adversely affect the inhabitants of the aquarium.

It is an extremely good plan, as an alternative to an aquarium of the size mentioned, to make several smaller ones, and these can be of any size, from one foot long upwards, with widths which are roughly one half of the length. It is sometimes possible to come across small aquariums in a second-hand shop which have been fashioned from a single piece of glass, this, of course, will save the making, and, on the whole, if several can be obtained, it is a better plan than to make one large one, and certainly not more expensive.

If the aquaria suggested above are either beyond the means, or not considered suitable for the purpose, here are one or two suggestions for overcoming the difficulty without spending a good deal of money. First, there is the usual fish globe, which may be bought for a small sum in almost any size. Then most naturalists sell propagating glasses, whilst

inverted cake covers, discarded from a confectioner's shop, have been pressed into service, fulfilling admirably the needs of the microscopist. Going still further down the scale to get something within the range of everyone, jam jars, especially those of the clear glass variety, can be made to serve. Going back for a moment to the inverted cake cover; we should stress perhaps that it must be made to fit in some kind of stand, otherwise it will be easily upset, and never really steady when wanted at the crucial moment. One suggestion, which has been followed successfully by a keen student of the microscope, is to pack the base of the cake cover into a shallow wooden tray, pressing round it moss, or similar soft material, which will wedge the receptacle firmly into position.

As a general rule, it is wise to see that, whatever type of aquarium is employed, it shall have as wide a mouth as possible. The water in them may be anything from six to twelve inches deep, though some naturalists are of the opinion that nine inches is the best all-round depth of water for a micro-aquarium. Whatever the shape of the aquarium, it will be necessary to have a sheet of glass sufficient not only to cover, but to overlap its edges. It is highly desirable, in the case of a circular receptacle, that the glass should be circular too. There comes the question of the admission of air for the benefit of the inhabitants of the aquarium; this can be done very simply by fixing some rubber or cork upon the edges. The admission of air is not so important as one would first imagine, because



A GNAT (*Culex Pipiens*) $\times 10$

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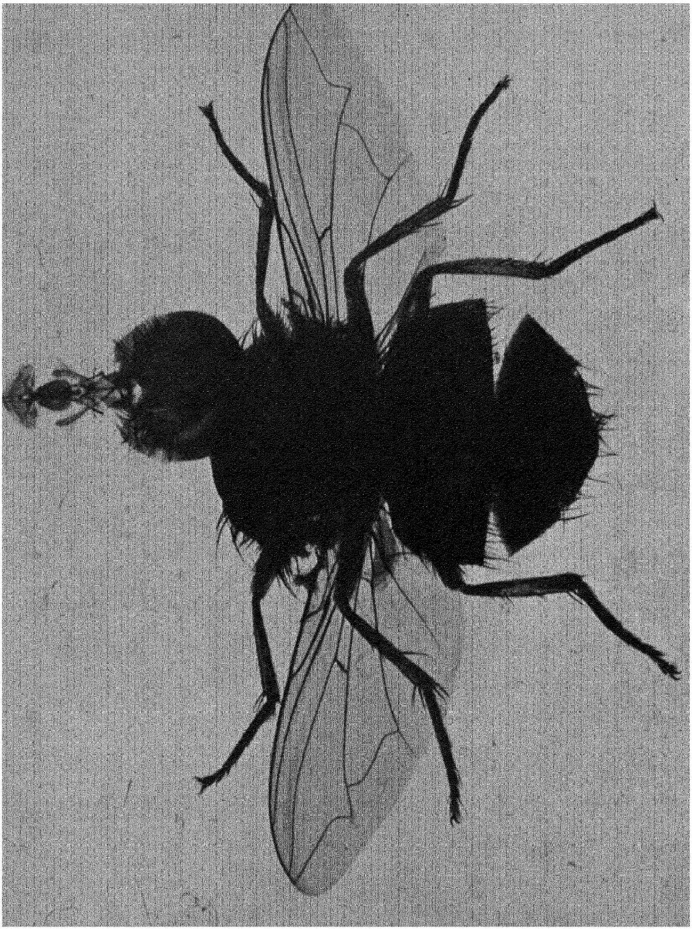


practically the whole of the inhabitants of the aquarium must breathe their air through the water, and there will be quite enough between the top of the water and the glass cover for normal circumstances, and it must be stressed that dust will find its way into an aquarium, unless it is almost hermetically sealed. The dust frequently forms a layer on the top of the water, and spoils many an opportunity of observing what is taking place there.

Another advantage of completely covering the aquarium, and this is especially true if it is left for some time, is that the usual loss from evaporation which is found with an open container is obviated. The vapour which would be lost in the process of evaporation condenses upon the under surface of the glass sheet, and falls back into the aquarium.

One great advantage of an aquarium of a fairly large size is that there is no necessity for changing the water frequently. It will be obvious that if the water has to be changed very often, it will not be easy to carry out prolonged experiments, nor will it be possible to watch the gradual developments of marine and fresh-water growth.

Up to the 'forties of the nineteenth century, those who worked with a micro-aquarium were severely handicapped because they found they could not keep the inhabitants in health (indeed, most of them died) without frequent changes of water; this, of course, not only took a good deal of time, but there was trouble in bringing the water from the shore. In addition, each time the water was

changed something was lost from the growth in the aquarium. From the period mentioned, however, it has been increasingly shown that it is possible to preserve a balance in an aquarium, whether it is of the sea or fresh-water type. Experiments were tried in which it was endeavoured to find some plant which could be grown successfully, whose main purpose in life would be to feed upon the carbonic acid gas which is given off by the live-stock in the aquarium. As plants give off oxygen, and the inhabitants of an aquarium need that gas, it was purely a question of arranging a balance; that is to say, that the plants should supply the animal life in the tank or aquarium with the needful quantity of oxygen. On the other hand, the plants would need a certain amount of carbonic acid, so that what the experimenter had to find was the proper balance.

It should be mentioned here that besides plants there are certain creatures, especially in the lower forms of animal life, which will give off oxygen. It was, therefore, possible to determine which of these tiny creatures were most suitable for the aquarium, and they gave their very powerful aid, small though they were, to the plants which were helping the rest of the animal life in the aquarium.

Another point for consideration is—what about light for the aquarium? Is there any particular light which should be striven for? Long ago, the old watch-makers came to the conclusion that their workshops should always have a north light, and undoubtedly for the aquarium one cannot do better

than place it in a window which faces north. It may be easier in a conservatory or greenhouse than in the ordinary residence. Whilst a position facing north is best, it is not absolutely essential, and naturalists report quite successful results in whatever direction their windows happen to face. It will be necessary, in any case, to see that there is some method of shading the aquarium, and this is particularly true of those which have glass the whole of the way round, and on the top as well. We have to remember that, in the natural order of events, the light can come only directly from above. Think for a moment of the rock pool; although here the light comes from above, there will nearly always be some shady portions, and when you have been collecting your specimens, almost unconsciously you will have avoided the shady portions because you could not see the creatures unless they were in the brightest section of the pool.

Wherever the aquarium is placed, it will not be difficult for the observer to determine how and where it needs shading. A piece of paper, especially brown paper, may serve very well, but if it is desired to make a much neater job of the shading, it is suggested that some kind of linen, preferably dark green, should be arranged to cover perhaps the top glass, with an overhang to prevent the sun's rays coming directly on the sides of the aquarium.

Having got the aquarium into position, the next point for consideration is its preparation for the inhabitants which you hope will live comfortably there. Great care is essential in every stage of those

which will now be mentioned; it would never do simply to bring in some stones from the garden, or even from the seashore, and just drop them in to form a bottom for the aquarium. Both stones and sand, and particularly fine gravel, should be carefully treated before they are put into the aquarium.

We have to remember that there may be some impurity mixed with a portion of the sand, gravel, or stone; this, with the sea continually washing over it with each tide, would matter very little to any inhabitant of the seashore, but when we place bottom material in perhaps a gallon of water, it is obvious that whatever impurities are there, they will be intensified, and probably prove destructive for the minute inhabitants who will shortly occupy the aquarium. Gravel makes an excellent bedding; it is also very desirable to obtain some pieces of flat stone, and also some rock, because the inhabitants of the aquarium will be varied. Some will prefer a stone with plenty of angles, whilst others will seek for a very flat, large pebble. You will observe that whatever you put in the aquarium in this way, it will soon have a curious covering; it is called a confervoid growth. It will provide not only food for some of the inhabitants, but a most useful and comfortable shade for them to carry on their business of life.

CHAPTER XV

THE MARVELS OF CORAL

One of the greatest wonders of the sea is the presence, particularly in the Southern Pacific, of numerous coral isles. For many years their formation was a much debated question, and it is only within a comparatively recent period that scientists have, by careful study of the coral under all circumstances, put out a theory which satisfactorily accounts for the atoll. Even now, on some details, the experts are not wholly agreed. The average sailor does not bother his head about the formation of the coral island, what he wants is to give it as wide a berth as possible. In fine weather the low-lying islet, with its palms marking it out more particularly, may be seen at a good distance, and the helm shifted to miss it. But in a fog or mist, in a hurricane, or at night, the coral atoll is one of the greatest dangers that lie in the path of any ship. Fortunately, the Pacific is now well charted, but it was not always so, and many a smart ship went to her doom on the sharp coral reefs which are met with before the white, sandy shore can be reached.

We are really concerned here with the marvels wrought by the coral insect, but it is necessary to have in our minds something of the formation of

a typical coral island, and so more readily follow the wonderful work that is accomplished by this hard-working creature. Many—indeed, most of the atolls, are oval in shape, though some are approximately round. Perhaps a horseshoe would fairly describe the shape of the majority, the inside of the horseshoe curve being the lagoon. Very often the entrance to the lagoon is blocked, save for a narrow passage or passages formed by islets. Inside the lagoon there may be one or more islets.

It seems incredible that islands which number thousands, if the Pacific and Indian Oceans are considered, should have been built up by the tiny coral insects. But whilst at one time doubt was thrown upon this supposition, it is now well established.

Whilst the main work has been done by what is called the coral polyp, investigators have come to the conclusion that there were allies who contributed something to the work once it was well in hand. Thus, there are seaweeds and various shell-forming animals which seem to have been attracted to the foundations of the work which the polyps were engaged upon, and, from accident or design, have added their quota to the monument of industry which testifies to the skill and energy of the polyp.

The investigators had got so far in determining how the atolls were built up, but, for many years, they were perplexed by two factors, the first that the coral isles were found in the midst of an ocean often devoid of other land; secondly, that their formation should be always upon the plan already

indicated. Obviously there must be reasons for this curious fact.

Rather more than a century ago there was a well-known writer of fairy tales in Germany—Von Chamisso, he added poems to his delightful stories for children, and on the top of all this he was an ardent naturalist. It happened that, in 1815, a German expedition was sailing for the Pacific to make various explorations and investigations, and they needed a naturalist. At once Von Chamisso volunteered for the post and secured it. The expedition spent three years in the Pacific, and they made an especial point of examining the coral formations.

The naturalist of the expedition became keenly interested in this work, and, after very careful observation and reflection, he propounded his theory that the shape of the atoll was really due to the fact that on one side the coral insects obtained a greater supply of food. On this assumption the atoll would grow higher and more quickly on the side facing the ocean, with the result that there would be a slope to the shore of the lagoon. It seems probable, however, that the German naturalist missed two important points. They were, first that although his theory of growth was undoubtedly the correct one, it was due to the greater supply of oxygen rather than actual food, which made the coral insects thrive more rapidly on the outer edge of the atoll. The other point, and a very important one, was that, contrary to what Von Chamisso believed, the marvellous insects, hard-working as they are, did not really build up their ridges from the bed of the ocean.

It should be mentioned here in explanation of the formation of the islet that the shores, and subsequently the tops of the ridges, possessing a soil in which palms and other growth are possible, are largely due to the action of currents which gradually bring flotsam and jetsam from other shores, and pile it up on the projecting coral reef until the island is made. In the same way the seed of the palm has been carried hundreds, and perhaps thousands of miles, to take root in the new land.

It happened that whilst the German expedition was still out in the Pacific, a French corvette, called the *Uranie*, sailed to that fascinating ocean, and was actually at work there during the last months of the enterprise in which Von Chamisso had done such good work. Aboard the *Uranie* were two naturalists, and they formed their own opinion about the coral atolls. In their view the coral insect could live and thrive only in comparatively shallow water. The Frenchmen thought that the coral polyp was really striving to get into shallower water by building upwards from a submerged mountain summit. It is necessary to stress that this theory refers to the reef-building coral insect only. There is good reason for believing that much of what is now the Pacific was once a great continent, and that, in all probability, South America was linked by land with Australia, and again, quite possibly, that the Indian Ocean had a continent, or a fraction of one, which linked Asia and Africa with Australia. The presence of reef-building coral insects in both the oceans mentioned certainly lends colour to this view.

The reef-building coral is rarely found *alive* at greater depths than ninety feet; Gaimard and Quoy, the French naturalists in question, thought that they would not be found at such a depth as this. Assuming that there was once this great continent where now the Pacific rolls majestically, then that continent would have its hills, mountains, valleys, and perhaps even volcano craters. When the waters swept into the lower lands, the higher hills and mountains would be the islands dotting the ocean. Such a theory explains those remarkable graven images on Easter Island, which have puzzled men for centuries. Assuming that Easter Island was the highest land of the great submerged continent, it is very probable that the statues were brought there as the water advanced; it is extremely unlikely that they were fashioned on the lonely islet, since they are the work of many hands, far more than such a small section of the earth could possibly maintain in food alone.

Now we are getting somewhere near the wonder of the coral isle, but it is worth noting that both the French naturalists fell into error in their deductions, even as their German rival had done. It remained for our own Darwin to hit upon the real explanation of this wonder of nature. The Frenchmen had to try to account for the inevitable lagoon when once they had announced an acceptable theory to account for the upward growth of the coral ridge. They came to the not unnatural conclusion that the site of a coral isle was also the site of a long extinct volcano, and that the crater had really caused the

lagoon. Soundings had been taken by the crew of the *Uranie*, and they gave some surprising results, leading the naturalists to the wrong conclusion. Bottom was found in anything from 200 to 500 feet, and there were several which baffled the men because they could not find bottom at all, even when they had let out every inch of their rope. Yet it was quite clear that coral insects had done their work at the bottom of the lagoons, because specimens of that work were brought up, and at from such depths that it was certain the insects could not live there.

Although some scientific people rather disbelieved the theory put forward by the Frenchmen, viz.: that the corals had built up their strange and wonderful edifices upon foundations placed on the rim of craters of once active volcanoes, a good number of years went by before a more satisfactory solution could be brought forward.

In 1842, Darwin, fresh from his own researches, largely settled the whole matter for the doubters. He pointed out one fact alone which rather discredited the theory of Quoy and Gaimard; it was that the atolls, in numerous instances, were very much larger than any known volcano, and that even supposing there were much greater volcanoes in the submerged continent than we possessed now, it was exceedingly unlikely that such volcanoes would exist in thousands over a comparatively small section of the earth's surface.

Darwin pointed out that the earth's crust was constantly changing, and that there was every evidence that the submerged portion of it shared

the same fate; therefore, he concluded, it was far safer to assume that the corals had done their work almost at the surface of the sea, and then Dame Nature had stepped in and lowered that work until it could be found at such depths that the coral could not possibly exist. This theory at once explained those very deep lagoons.

Darwin, with his usual clarity, further elaborated his theories, and although much has been learned since, they are, in the main, unchallenged to-day. He stated that there were three distinct classes of reefs. He believed that the first class, which he called fringing-reefs, began their career in the shallower waters found near the coast. Darwin went on to explain that the reefs upon which the corals were at work began to sink, but so slowly that the tiny creatures were able to keep up sufficiently near the surface to thrive; always they had to be at work to get higher and higher. If the reef sank quickly, as it sometimes did, then came an end to the endeavours of the corals; they just died, and then, perhaps years after, their delicate building was fished up to be the wonder and delight of people in distant lands.

Darwin was convinced that the corals on what we may call the outer side of the reef thrived most, and this, by the way, fits in with the earlier theory of Von Chamisso. The land, it is assumed, still goes on sinking until the reef is quite separated from the land to which it was at one time attached; the space between the land and the reef then becomes the lagoon. Now comes the next class of reef—actually what the fringing-reef has become—this is known as

the barrier-reef. The name was given because the reef now formed a distinct barrier between the open sea and the still waters of the lagoon.

If we assume that the land was an island, and the sinking is going on all over its area, we shall also have to assume that the corals are at work on a reef surrounding the island. But whilst the land is sinking, the polyps are vigorously at work, building against time as it were. The next stage in the formation of the coral isle is the gradual sinking of the enclosed mass of land, which leaves a small islet in, perhaps, the centre of the lagoon, and then slowly that goes, too, beneath the surface. In point of fact—and strongly supporting this theory—there are often islets still left in the lagoons, some of which show clearly that the polyps have built up on the disappearing remains of the final piece of land, whilst, in a few instances, the crown of land remaining appears not to have been due to the works of the corals, but the survival of the original island.

There are many dangerous reefs, just covered by water, in the Pacific; these undoubtedly mark the grave of an atoll, a Polynesian name which Darwin found convenient for the description of the circular, or oval-shaped coral island, which is really the third class of coral reef. Whilst many remain, it seems highly probable that far more have sunk towards the beds of the Pacific and Indian Oceans; it is only when they have gone down a few feet that they really constitute a danger to navigation.

It is thought that the extremely long series of atolls found in various parts of the Pacific mark the

sites of former mountain ranges. Darwin advanced this theory with others, and it is now usually accepted.

There are many islands, and particularly groups of islands, in the Pacific which are purely volcanic in origin; on these life is not only possible but exceedingly pleasant. On the contrary, it is either precarious or impossible upon the coral isles. They are usually short of water, deficient in vegetation, and are liable to be swept by the tremendous gales of the Pacific; these have been known to sweep a low-lying atoll absolutely clean of everything upon it. In addition, they are liable to be affected by tidal waves which have originated in an earthquake. Rain, when it falls, sinks through the white coral sand, and although, in cases where an attempt has been made to establish a village upon one of the islands, receptacles have been provided for catching the rain water, the scheme has proved quite inadequate. The natives subsist upon the milk of the coconut which, fortunately, seems to be quite at home and happy on the sandy soil. So torrential is the rain at times that it is recorded on good authority that natives have been seen to go out on the lagoon and skim the fresh water from the top of the salt.

The living coral insect, or polyp, is frequently so minute that it must be brought under the microscope if it is to be examined; on the other hand, some of them are so large that they measure several inches across, a few exceeding a foot in diameter.

Most of us think of coral as the substance resembling calcified lime which we see in museums, or have

brought home to us by friends from the tropics. These are but the shell, as it were, whilst the important and wonderful kernel is lost to us. The polyp takes a cylindrical shape, and it is armed with a series of remarkable tentacles, which stand out aggressively at the end of its body; the other end is attached to the rock.

One observer describes this business end of the coral polyp as resembling very closely the starfish. These tentacles are fitted with sting cells, and they are employed to kill the prey of the polyp. The tentacles can be withdrawn within the cylinder, leaving either a rosette at the top—when not fully withdrawn—or just a small aperture when the tentacles are pulled within the cylinder altogether. The cylinder is covered at its base and sides by a series of wonderful cells; these appear to be employed in securing the carbonate of lime from which the wonderful fabric we call coral is built up. It is a slow process, of course, and innumerable polyps are at work in the construction of those remarkable reefs which we have noted here. Little by little the carbonate is withdrawn from the sea water, added to the body of the coral insect, and when it dies the structure remains.

The work of the polyps takes various and very beautiful forms; these may be studied at any well-found museum, but in every case the gradual evolution of a branch or section of coral can be followed, especially if a hand-glass is carried to the museum in order to get a closer view of this marvellous work of Nature. Much of the coral seen in museums has

been lifted from the ocean bed in what we might term a live state.

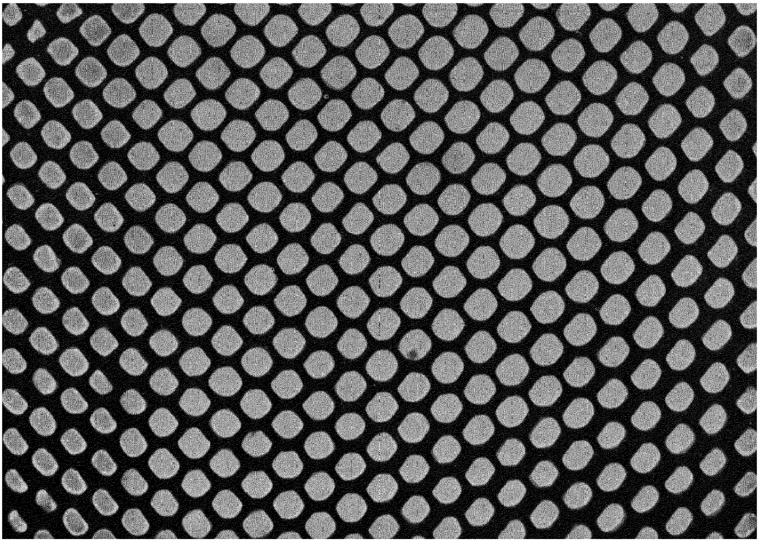
Some time ago the United States Williamson Expedition was sent out to the West Indies to explore, by a novel method, the seabed in this tropical portion of the world. The results attained by the use of a submarine observatory were very remarkable. Quite apart from the fairylike grottoes which were photographed at the bottom of the ocean, Mr. Williamson was able to arrange for the raising of some of the largest sections of coral that had ever been lifted. These were subsequently despatched to the American museums, where they have been a great source of interest. As the polyps were still at work when the coral formation—weighing over four tons—was raised, the leader of the expedition found it necessary to kill off the industrious insects. This was accomplished by the use of chemicals, and, after a thorough bleaching in the sun, the rich prizes were sent off to the States.

CHAPTER XVI

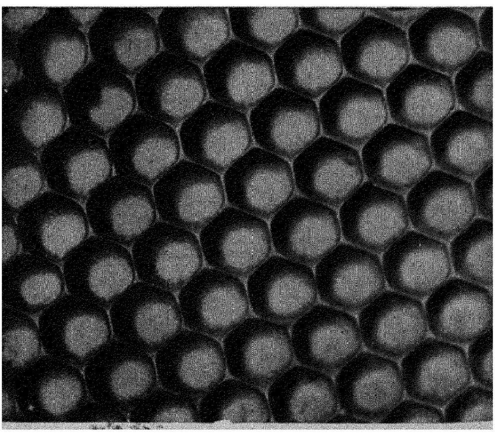
THE MARVELS OF POND LIFE

THE MICROSCOPIST will find in the average pond a wonderful source of interest for his lens. Practically every pond abounds with minute life, and it needs only the merest dip of a bottle to secure enough specimens to last quite a long time. It is necessary, however, that the collector from the pond must know something about what he should collect; then he can take a wide-mouthed jar, and, dipping into the water, bring home quite a number of specimens. Whilst he is about it, he might just as well catch those which are really worth while.

First he should consider his equipment, much of which may be home made. It is a good plan if the hobby of microscopy is to be followed with real zest, to obtain by purchase several of the adjuncts which are particularly needed for pond hunting, and see what can be added by making articles at home. There is what is sometimes called the Collecting-stick, although it is quite usual to hear it spoken of as the Pond-stick; this, if purchased, will cost at least ten shillings, probably more. At first sight it might be thought that the pond-stick was simply an ordinary walking-stick, but a close examination shows that it has a screw-ferrule which can be unscrewed



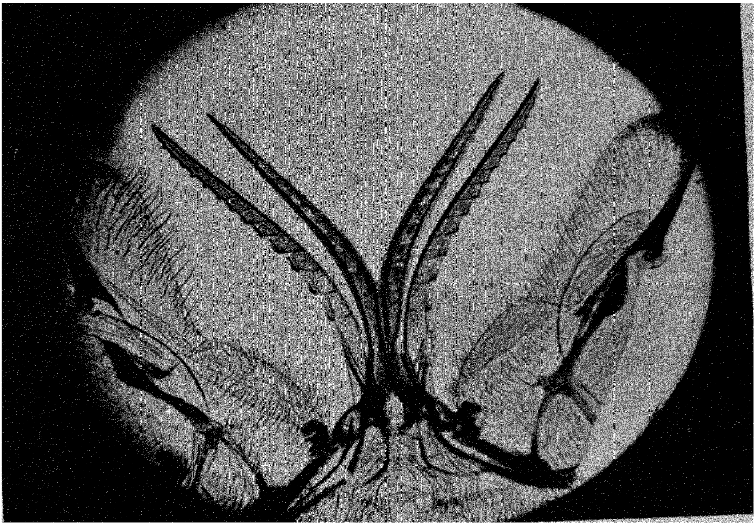
Some of the Facets of the Eye of a Gadfly



This shows the Facets in Closer Detail

These facets are all lenses, and each eye of the fl
contains between two and three thousand of them

[*Face page* 150



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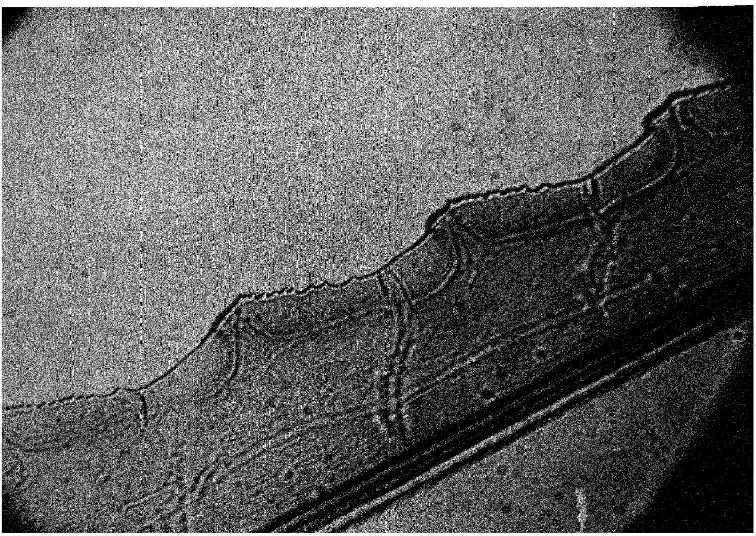


PORTION OF THE SAW OF A SAWFLY
Showing each tooth on individual saw.

Face page 151]

and when removed allows an inner jointed section of the stick to be pulled out; the net result is that the yard-long walking-stick becomes double that length. It will be found that the end of the extensible portion is fitted with a small brass tube, which, again, is fitted with a hollow screw into which a whole series of fittings can be fastened.

There is, for instance, the collecting-bottle which is fitted with a clip round the wide neck; the curved jaws of the clip have an extension which will screw into the pond-stick. The collecting bottles are liable to be broken and it is a good plan, therefore, to buy two, keeping one in reserve; they are quite cheap, and as a rule can be purchased at a chemists. It is very desirable, in working with the collecting-bottle, that some skill should be attained in securing material both from the top of the pond and at some greater depth below the surface. It will not be long before the manipulator is able to do exactly what he wishes with the pond-stick and the collecting-bottle, but with his first attempt he does not usually secure the results that he sets out to secure. It is so easy to plunge right in, instead of skimming the surface; it is merely a turn of the wrist which will allow of the correct results being obtained. It will be surprising to the novice what a vast difference in the water—or rather its contents—will be found if it is taken at various depths of the pond.

The regular pond collector has a name for these various depths of water, and as a rule he carries another bottle which will allow him to retain the myriad life which thrives in the pond-water,

whilst getting rid of the unnecessary liquid. The name given to the pond mixture is broth, and the collector means by that water which is swarming with life.

The keen collector carrying a second bottle will have fitted into it a cylinder made up of remarkably fine copper gauze; as each different scoop of water is obtained at varying depths from the surface, it is poured slowly through the cylinder, whose purpose it is to retain the captures whilst allowing the water to run away freely from the neck. Some collectors have instead a filtering-bottle, but this is by no means a cheap addition to the outfit of the pond-hunter; even the wire gauze strainer is not exactly a cheap fitting, but it may be home-made by simply buying a square of the material and then tying it round, so that it forms a cylinder. It is better still if the joint can be made with solder.

A useful home-made article can be provided at much less expense if desired. In this case an ordinary jam jar, preferably a tall one, and holding somewhere about a quart of water, is chosen; the top is filled by a thick cork, such as are found in large pickle jars, and then two funnels are obtained and about ten inches of india-rubber tubing. The mouth of number one funnel is covered with fine muslin which will allow of the water passing through, but nothing else; these funnels are fitted into holes bored into the cork, and it must be seen that they are firmly held in the neck of the bottle by this means. It should be mentioned that whilst number one funnel goes right side up in the cork, the other has the mouth downwards

and only a small section of the stem protruding above the cork. This inverted funnel is the one whose mouth is covered by the fine muslin, and to its thin end is attached the rubber tubing, its object being to serve as a syphon.

As the water is collected in the collecting-bottle it is poured into the filtering-bottle via the wide mouth of the funnel; when sufficient water has been placed in the filtering-bottle, it will reach the muslin-covered mouth of the inverted funnel. When it has gone still further and has risen an inch or two above the mouth of the inverted funnel, the syphon arrangement may be started, with the result that all surplus water will be drawn off, whilst the whole of the creatures remain in the filtering-bottle because they cannot escape through the muslin. For easy carrying some sort of handle should be fitted round the neck of the bottle.

It will be obvious that using the collecting-bottle must involve the bringing out of the pond a good deal of material and insects which will be of no use for the aquarium, which, in turn, is a store-house for objects for the microscope. It is, therefore, a good plan to exclude the larger growths from the filtering-bottle; it may be done quite easily by fitting into the inlet funnel a disc of perforated zinc, this will allow all the smaller creatures to go through into the filtering-bottle, whilst preventing the larger insects going down. If a piece of perforated zinc is not readily obtainable, the same purpose may be met by taking a tin-lid from a box and with a hammer and nail perforating a series of small holes.

Some collectors suggest that it is better to remove the unwanted animals from the collecting-bottle before pouring out its contents into the funnel. This may be accomplished quite easily by means of the dipping-tube, which, in any case, will form part of the equipment of the pond-hunter; its use has been described elsewhere. It is a very handy instrument, and the collector will hardly be able to manage without one or more dipping-tubes.

One objection to both the collecting and filtering-bottle is that they are cumbersome to have to carry far afield. It is possible, however, to secure practically the same results with a much smaller piece of apparatus; this consists of a considerably smaller collecting-bottle which is surmounted by a ring and net. The diameter of the ring is usually about six inches, and the net is made from muslin, which, though fine enough to retain small animals, is yet sufficiently coarse to let the water escape readily. The net, in action with the bottle to which its converging bottom is attached, resembles very closely the funnel already described as used with the filtering-bottle. It is a good plan to buy a ring readymade, as it is essential that it should have the screw-adjustment to fit into the stick; in some cases the muslin is already attached, but, as it frequently gets torn or rots, the collector will have to practise stitching on fresh material; probably one of the women-folk may be induced to undertake this work.

An improvement on this type of ring-net is where, instead of the collecting-bottle being fitted direct to it, a glass tube forms the termination of the net,

the tube is secured to this termination by an india-rubber ring, such as is used with umbrellas. The great advantage with this arrangement lies in the fact that a very much smaller collecting-bottle can be carried along, as it is really the contents of the net which are transferred to the bottle, most of the water escaping through the muslin. The brass rings used for this purpose vary in diameter, and some are as small as three inches. These have been adopted so that they can be carried quite easily in the pocket; a sponge-bag provides a useful receptacle for the ring and net, when on the small size.

The apparatus which has just been described, is very useful in securing what may be termed the Free-swimming Rotifers, Infusoria and Entomostracans. Whenever possible a sunny day should be chosen for securing the objects mentioned above. In favourable circumstances they will be found in swarms on the surface of the water, and it is quite an easy matter to scoop them up. It may be well to mention here that it is a good plan to make a considerable number of efforts with the net at different parts of the pond. In this manner it will possibly greatly increase the variety of the catch.

There is another important point for the pond collector, and it is that the bottle should be filled with water, otherwise the shaking which it is bound to sustain when it is being carried, will kill off a great number of the tiny organisms that will be found in the water. At the same time, it is well to remember that overcrowding is just as bad for these water-dwellers as it is for other insects and animals. It

is only by experiment that the collector will learn how much he can hope to bring home from a morning's operations.

We have mentioned that a bright, sunny day is highly suited to secure good sport with these tiny creatures; this does not mean, however, that a sunny day is essential, for a dull, cloudy afternoon or morning is really just as suitable for securing other specimens; these, for the most part, will be found in the weeds and other vegetation growing on the banks at the point where they meet the water.

One of the drawbacks which the collector will often find in making his selection from the pond, is the fact that most ponds are covered thickly with duckweed; it is necessary to clear a section of the pond from this growth, and it may be best done by using the net for the purpose. When a clear space has been obtained, the net can be turned inside out and a real start made in collecting the necessary specimens.

On reaching home the contents of the bottle will have to be dealt with as soon as possible. It is a good plan to strain the water with very fine muslin so that the smaller creatures escape into another receptacle, whilst the larger are transferred to various smaller bottles. Do not forget that the tiny creatures will require pond-water if they are to live; quite a number of specimens have been lost to the microscopist through the fact that the collector believed that ordinary tap-water would do for their nourishment.

Some collectors say that horse-ponds are the best

breeding grounds of the larger Infusoria, whilst many Rotifers will also be found in the clearer parts of the horse-pond. Avoid, if possible, the ponds which will be found in fields without the shelter of trees; the falling leaves seem to help in the breeding of these strange creatures. Always carry the pocket-lens, and, having dipped and obtained some of the water from a doubtful pond, subject the bottle to careful scrutiny, and if the results are poor, go on to another.

It is good advice to give to a young microscopist that he should make a point of joining a Field Club; there are few districts without such a club, and it is quite certain that not only will it help him very much in his hobby, but it will almost certainly place him in contact with others whose interests are similar to his own.

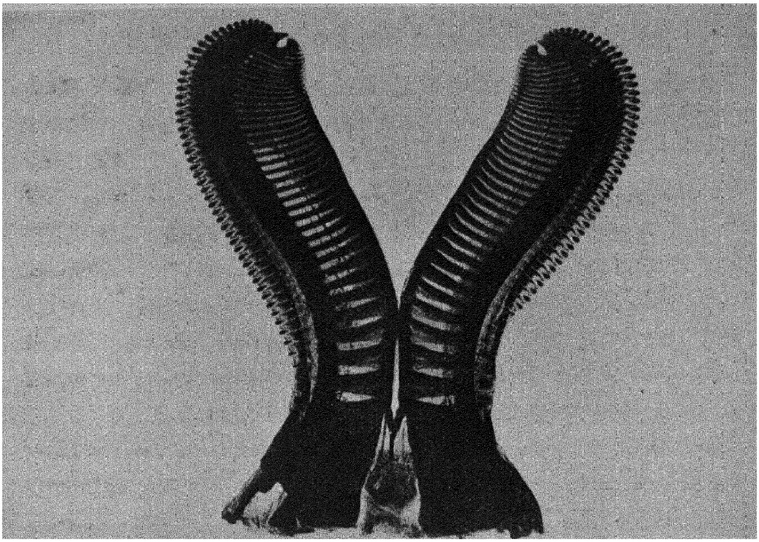
The membership of a Field Club, apart from the comradeship which always exists, will often allow of a break-away from specimen hunting, that is to say, not every ramble will produce numerous specimens. On the other hand, it will be rare that a Field Club ventures forth without obtaining a few objects of great interest which may be brought to the lens.

Members of a Field Club who are particularly interested in the microscope are rather keen on carrying with them all the apparatus which has been described. The pond-stick, with its screw-top into which various articles may be fitted, can have additional items added to this equipment. These, although not essential, are strongly recommended

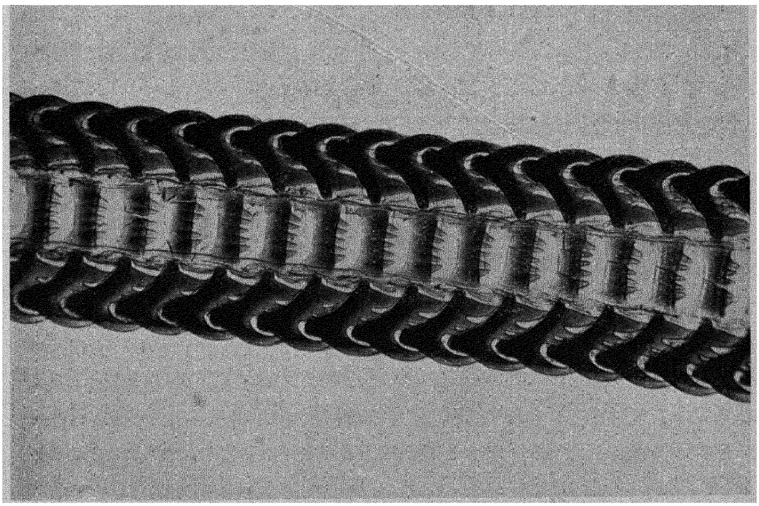
either to the individual collector, or, better still, as the common property of the membership. It is, indeed, a very good plan that the whole of the collecting apparatus should be held in common, not only is there a good deal of saving in original outlay, but it is quite obvious that there will be far less to carry. When we consider the numerous bottles which will almost certainly be taken along, it is highly desirable that no additional apparatus beyond what is actually necessary should be taken.

One of the most useful additional items which can be added is often called the cutting-hook; this screws into the head of the pond-stick. It is something like a scythe which has been bent to form a smaller curve. To look at it one might say it has the figure of a "?" mark. This fitting is particularly useful for reaching out to, and cutting off, weeds that are some little distance from the bank.

Still another very useful adjunct to the pond-stick is the Drag. This has three rather blunt-pointed hooks, fastened into a pear-shaped piece of wood, which, in turn, has an eyelet to allow of a strong cord being tied thereto. In some cases the drag has a pear-shaped piece of lead instead of heavy wood; where wood is used, it must be of a kind which will not float. Either of these items can be made by any fellow clever with his hands, but, on the whole, however, we should recommend their purchase. Some collectors find that the drag is very much easier to use than the cutting-hook. If you are working by yourself it is suggested that a cutting-hook should not be purchased, but reliance

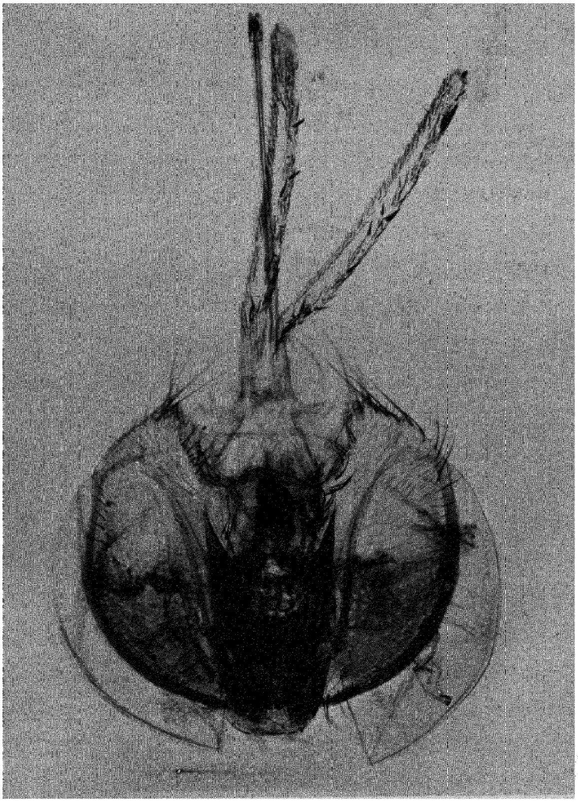


REFLEXED SAWS OF A SAWFLY × 20



THE PALATE OF A WHELK × 20

[*Face page* 158



HEAD OF A TSETSE FLY ×20
These are deadly flies which carry sleepy sickness.

Face page 159]

placed upon the drag for all purposes; it is certainly handier in use, but if a Field Club is formed it is desirable that a cutting-hook should be added as well. The provision of both items allows two members to work together on the same class of work.

The particular use of either adjunct of the pond-stick is the securing of branches, twigs and submerged plants from the bottom of the pond. In most cases it will be found that the items brought up by the drag are veritable store-houses of insect life which would otherwise evade the collector.

It will be obvious that a good deal of what the drag brings up will not be carried home with any comfort; it is, therefore, a good plan to pack a number of corked glass-tubes, such as are used in laboratories, and scrape off what is obtained from the twigs and branches, and also from the weed where it cannot be conveniently cut up into small sections. It is desirable to include in the outfit for pond work a pair of forceps; these will enable the small pieces of weed and twigs to be handled without difficulty.

It is impossible here, to describe the vast number of specimens, most of them with very long names, which can be obtained from the pond. The best plan is to bring home the trophies and study them carefully under the microscope, mounting the best for a permanent record. Half the fun of the microscope lies in being able, by your own investigations, to determine what kind of specimens you have obtained. This is possible by comparing the magnified creatures and vegetable specimens with the photographs and drawings given in this volume.

An old collector suggests that a section of a ground-sheet should always be carried with the equipment; indeed, he goes further when he recommends that in the case of a Field Club a complete ground-sheet should be taken, the idea being that the members can kneel upon it whenever the ground shows signs of dampness. It is rare, indeed, that the banks of ponds or rivers will be free from dampness, because, even in dry seasons, the ground absorbs the water from below it.

When hunting by streams and rivers it is desirable to keep a good look out for leaf-bearing mosses; these are usually found just above water-level. In some cases they will be discovered upon the roots of willow trees just below water-level. These mosses, apart from being capital objects for the microscope, have often produced some of the most remarkable Polyzoa. It is desirable to detach a fairly large section of moss and, with your hand-glass, examine it very carefully, pulling it apart in order that nothing shall miss your close scrutiny.

Keep a good look out for bricks and stones which probably form the base of a bridge or wall which has been long under water; all kinds of really wonderful creatures and plants will be found upon the old masonry.

We mentioned the ground-sheet; it is a very good plan to make full use of it, and if the club has several sections of plants or branches which have been obtained from the water which cannot be dealt with satisfactorily on the banks, they can be packed in a ground-sheet, made up into a parcel, and carried

between two members. It is, therefore, a good plan to carry either straps or stout cord for this purpose; if the pond-stick is a fairly stout article it may be run under the straps of the ground-sheet, and it will be more easily carried if two members each take one end of the pond-stick.

There now comes a question as to how the outfit may be best carried; again the ground-sheet may be pressed into service and the various articles which we have described may be packed securely into it. This is a plan which cannot be fully recommended, however, since we have to remember that a good deal of the outfit will consist of bottles; it is a far better plan to secure a satisfactory handbag or else a not too large suitcase. The bottles can be kept separate and also upright in either class of bag, but it is very advisable to use some kind of padding to prevent them constantly chafing together, or perhaps breaking. If the bag or case has a certain amount of stiffness it is an excellent plan to have some loops of tape, or, better still, fairly wide elastic sewn into the lining to keep the bottles both upright and out of contact with each other.

It is also possible to press baskets into service; these need to be of a fairly large size, and the best are those similar to the baskets carried by railway servants, but they would need to be on the large size for the collector.

It is an excellent plan to save all miniature bottles and vials such as are used by chemists for small quantities of medicine, and particularly for tablets and powders. These make excellent collecting

receptacles, and it is impossible to have too many of them.

It follows that the apparatus described for the pond-hunter, will also be found extremely suitable for the examination of the collections from the rock-pools. Too many of us must always live away from the sea, and it is not, therefore, worth while providing special apparatus for the annual holiday by the sands.

CHAPTER XVII

THE MARVELS OF MYCETOZOA

THE MICROSCOPE is constantly adding new wonders to those already known, and sometimes we are tempted to ask how far can we go beyond present knowledge. The truth is that modern instruments have the effect of spurring on to further effort. As a pastime or a profession the work with the microscope is one of great fascination, and it is safe to say that the convert to the hobby will feel the urge, constantly, to enlarge his studies, and, if possible, to add to them some amount of exploration on his own behalf.

The microscopist must venture in places which others would shun, finding there a rich field, and something well worth while doing. He may escape from the rush and worry of the world with his magnifying glass and specimen box, and then come home with a rich store of objects which will keep him happily employed for many a day—also outside the rush of modern life.

To mention the exploration of a swamp to the ordinary person conjures up a dismal picture; a place to be avoided, a district where ill-health can certainly be found with ease. That is hardly fair to the swamp or marsh, for whilst a good deal of it is true at certain seasons, there are others when the

marshland is not so very different from other low-lying districts, especially when the sun has cleared up the stagnant pools and dispersed the unwholesome mists. In addition, the marshland has its own beauty, whilst its vegetable and insect life offers a perfect paradise for the microscopist. There are certain forms of life, particularly those which are given the name mycetozoa, which can only be studied in a swamp at their best, and even there they will need careful search if sufficient varieties are to be found for the microscope.

It is generally admitted that this curious growth is propagated by the spores being distributed in the air, mainly by currents. They have, therefore, a distinct difference from other spore-bearing members of the animal world; these usually produce their spores whilst immersed in water, whilst others of the parasite family reproduce within the fluids of their hosts. Thus, the mycetozoa resemble very closely fungus, and indeed are often classed with that curious growth.

They have an especial interest for the student of nature in all her moods because a good deal of controversy has taken place in scientific circles as to whether mycetozoa belong to the animal or the vegetable world. They are certainly upon the border line but, on the whole, the view seems to be that they belong to the animal section of life. They seem to rejoice in homes founded upon the bark of decaying trees, but they can be discovered upon almost any surface which has direct contact with decaying vegetable life; they must have moisture.

Some of the best and most beautiful examples seen under the microscope have been obtained from a heap of tan which has lain some time and which has absorbed a sufficient quantity of moisture. For years observers were baffled as to how the mycetozoa got into the tan-yard, probably right in the heart of a big town, but the theory that the spores are carried by air currents will account for this.

If a tan heap can be discovered, a careful search should be made for mycetozoa, and specimens should be selected for first examination with the hand-glass and then transferred, with great care, to the specimen box. These curious objects are known as the "flowers of tan," and under the microscope they reveal a wonderful range of colours and delicate lines.

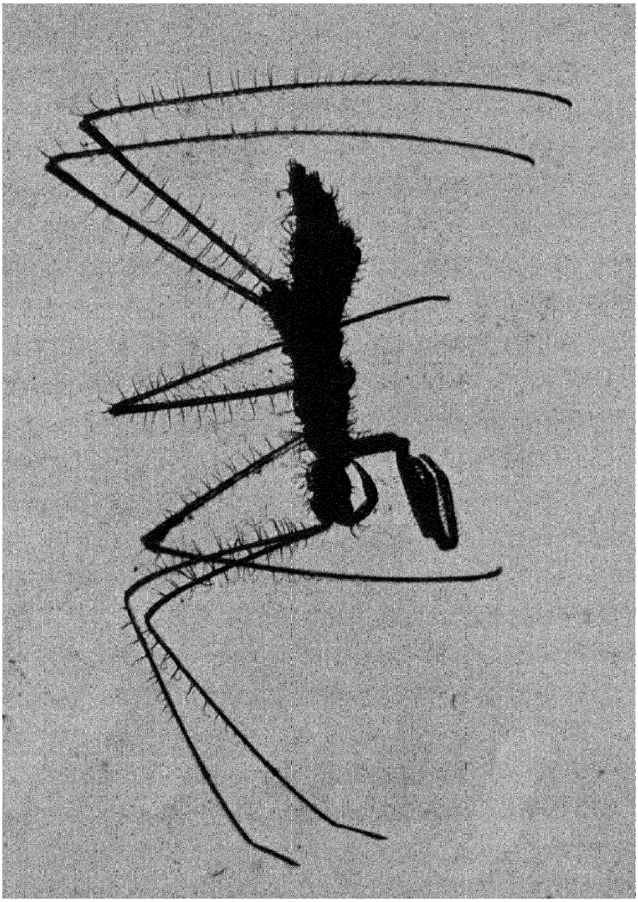
Mycetozoa is well distributed over the whole world, the main consideration for their propagation being moisture, wind currents, and decaying masses of timber and similar growth. It is thought by some observers that nature has produced the mycetozoa to aid in her work of reducing useless dead wood to a substance which becomes at once a valuable fertiliser.

Let us look for a moment at the life story of this wonder of the marshland and swamp. We have already noted that the spores are borne, like the seed of the dandelion, upon air currents. Much is lost, since it falls in many an unfavourable abiding place. But quite a good deal of the tiny seeds find either a fallen tree trunk, or, failing that, some decaying vegetable matter in which they can begin

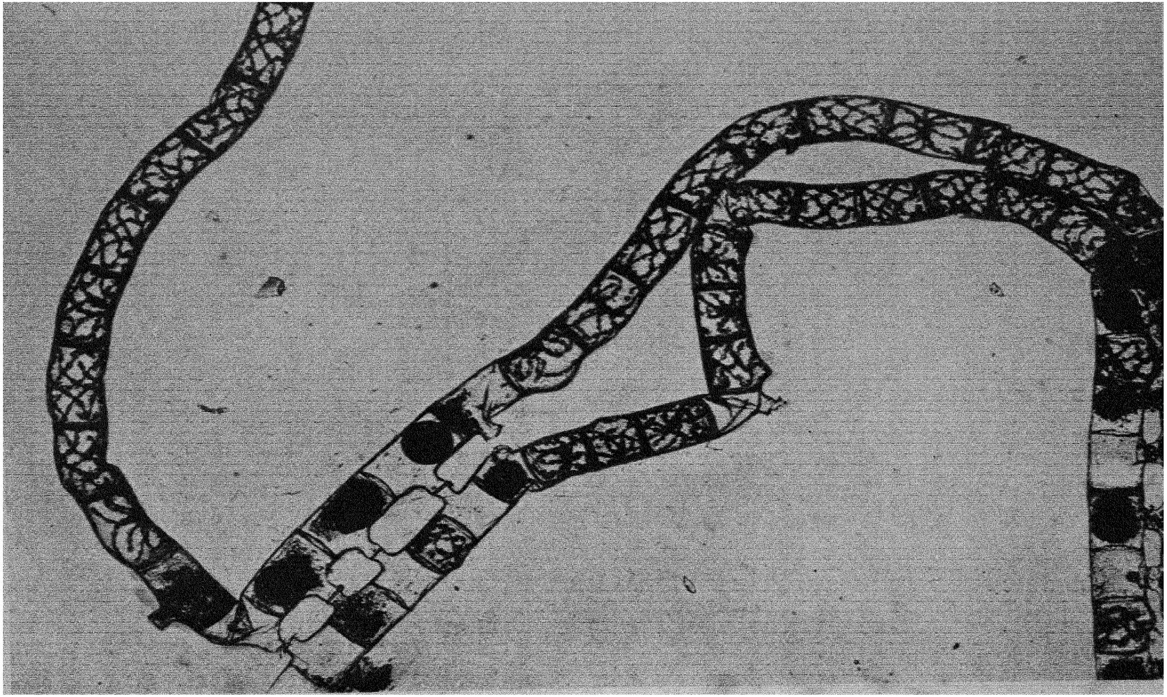
life in earnest. Though very tiny when in the air, owing to the spores having shrunk exceedingly, they soon absorb the moisture from whatever object they happen to alight upon; at once the spores take on the spherical shape, which, in their shrunken condition, they have lost. Not all the species are spherical, but the vast majority have this form.

Let us assume, for the moment, that the spore falls in a shallow pool instead of upon vegetable matter. Within a few hours a change takes place: the walls of the spore burst asunder and out peeps the tiniest thing imaginable—a protoplasm, which, perfectly colourless, and not to be seen with the naked eye, is floating upon the surface of the pool. If we were able to secure a spore and treat it at home, the next stages would be full of interest. The next development is towards an elongated structure, something like a small carrot in appearance, and having the long tail that a young carrot throws downwards, the tail, in the case of what is now called the zoospore, being almost, if not quite, as long as the body. Now the zoospore begins to swim to and fro, its motion being best described as resembling a dancing movement.

Like all other creatures, the zoospore is hungry, and it must eat to live; therefore it searches the water and quickly finds that unseen bacteria which is present everywhere. As it grows quickly in the water—and we will assume for the moment that it is in a glass tank at home for observation—it is far easier to follow its movements. A really powerful glass will show the remarkable business of digestion



WOOD BUG (LARVAL STAGE) × 15



Spirogyra in Conjugation × 50
Form of marine life which can have altered little in thousands of years.

[Face page 167]

going forward within that tiny body, which, by the way, has a knack of changing its shape, taking on some very remarkable forms at times. Assuming there are other zoospores, there now takes place a fusion of several, and we must be prepared to lose sight of the curious little fellow we have had under observation. In all probability none of this fusion will have been observed in the glass tank, unless, as already noted, several zoospores were introduced, unless, again, circumstances being very favourable, the original zoospore has increased by producing a series of young ones.

Now let us get back to the swamp again—or shall we say bogland? Here very interesting experiments can be carried forward by the use of damp blotting paper, and some most fascinating examples of mycetozoa obtained for the slides of the microscope.

Assuming that the tree, or whatever the mycetozoa are found upon, has become dry, the dampened blotting paper may be used for a most interesting experiment; it becomes a trap for the unwary outer portion of the mass which is usually called plasmodium, i.e., the name given to the united mass. The absence of moisture seems to cause the mass not only to become shrunken but to lose its energy, if we may use such a word in this connection. The wet blotting paper is carefully introduced so that it actually touches the fringe of the plasmodium; in a very short time the careful observer will see the latter crawling on to the blotting paper. It is now possible to bring the plasmodium home for further observation at leisure. The blotting paper may be

kept damp for observation purposes, it may be dried rapidly or slowly, and, in each case, there is a change in the plasmodium. Some scientists, in their experiments, state that they have kept it alive for years, so tenacious of life is the curious and minute growth.

Have you ever noticed a fallen log which has been so long on the ground that its timber is all soft and mouldering, and observed upon it a kind of red coverlet? Not the red blotches which are hard and shiny, but something which looks like the pile upon a really good velvet carpet. It is obviously a fungus kind of growth, but it is worth careful examination, for it is by no means common in Britain. You may think them fungus, purely vegetable in character, until you bend down and stroke the velvet-like surface. Then comes a surprise; if circumstances are favourable the supposed fungus will take wings—apparently. Actually a small cloud of spores will be started from their bed, and will most probably alight farther along the trunk or be lost on the ground. Look carefully at your hand, and you will notice that the red colour is there right enough. We assume that you have your magnifying glass in your pocket; have it out immediately and look carefully at the undisturbed growth first of all. At once the tiny pin-heads become miniature toad-stools under the glass, and they are found to be of surpassing beauty. It is here that the power of magnification is of the greatest value; without it half the wonders of the world would be lost to us.

Many of us have observed the trace of a snail

along the ground, or particularly upon a tree trunk —the long, rarely straight line of silver left by the animal. Those who have studied mycetozoa say that they appear to leave a similar trail at times; certainly they move, often in mass formation, and at others in almost single file. There seems no definite plan in their movements, but one authority says that it is the beginning of the stage when the spores will be thrown to the winds in order to form fresh colonies elsewhere.

Another observer records that a mass of mycetozoa which he kept under close observation for some days moved like an open fan, spread out from a central axis; it seemed to him that the main body was reluctant to move its quarters entirely, and he formed the theory that the fan-like movement was undertaken in an exploratory sense. For some days he was rather puzzled to find that there was a substantial increase in the mass, yet he could not, at first, detect how the increase was accounted for. On closer scrutiny, helped with his hand-glass, he found that there was a crevice in the rotting log, and that the re-inforcements must have come up through the crevice. He thinks they were trying to reach daylight, and that possibly the pressure of the mycetozoa from within compelled that already without to move along the log.

Further close observation showed that the moving mass had quite an aimless kind of progression, and that, here and there, it recrossed its track, but never did it get very far from its starting place. The observer was able to trace definitely the path taken

by the mycetozoa by the organic refuse which so clearly marked it. After the fruitless journeyings were done the mass began to break up into small particles, something about the size of grains of mustard seed.

Then came a marvellous series of changes, which could only be appreciated by the watchful eye aided with the magnifying glass. The detached and minute objects took on various colours, ranging from silver to pink, and, under the glass, they resembled nothing so much as delicate pearls, which were being gradually changed in colour to attain a greater beauty. Next stalks began to appear, and so gradually the tiny pearls were raised upon red supports, which were so delicate that they might have been spun from a fairy loom.

This was the beginning of the end, for the growths were now ready for the next stage in the circle of their existence—that of being broadcast to the winds in order that the whole process might begin over again, and go on *ad infinitum* from spore to plasmodium stage.

There are many varieties of mycetozoa, and each has its own particular method of developing from seed to harvest, but, in a general way, what we have described for one is the basis upon which all the others move.

The subject is so complicated, and the opinions so varied, that we do well not to be dogmatic, and must admit that we cannot say whether the objects are really animal or vegetable; they seem to have the attributes of both, and that is why they are so puzzling

to the scientists and the naturalist, whilst quite beyond the apprehension of the average person. All that we can do is to indicate some of the discoveries made concerning them, and enjoy this most marvellous working of one of nature's side-lines.

Mr. William Crowder, an American naturalist, has made an especial study of mycetozoa; in particular he has produced a very remarkable set of paintings taken from life under the microscope. These pictures were reproduced in the *National Geographic Magazine* a few years ago, and their publication led to an increased interest in mycetozoa on both sides of the Atlantic.

In America the growths are often termed slime moulds, and already more than five hundred species have been catalogued. Many of them are so minute that if they grew singly they would not be observed without the most careful scrutiny, but, as they are almost invariably found in masses, they are easily discernible. For the most part, the slime moulds are less than a quarter of an inch in height, and few things in nature take on so many forms as these varied examples. In nearly all cases germination follows the effect of moisture upon a spore, which may well be termed the egg of the mycetozoa family.

The germination has already been described, and it is surely one of the most remarkable developments in the world of nature. The spore cases of some of the mycetozoa, when examined under the microscope, appear as if formed from the most delicate porcelain, fairylike in design and texture. These are really the egg-shell of the seed of this marvellous

growth. One such form of mycetozoa is known as the Physarum family and, again under the microscope, the spore case resembles not only very delicate porcelain, but the general appearance is exactly that of a crinkled golf ball poised upon a stalk as if to give a good lead off for the player. Whilst some have been likened, by a tremendous flight of fancy perhaps, to a golf ball, there are others which are glossy black, whilst still more beautiful is a species which is a brilliant scarlet. The black variety have the power of reflection, and several observers have at first thought they were blue instead of black, but a glance at the blue sky overhead has given the necessary explanation.

Plasmodium has been mentioned earlier; this, in substance, resembles closely the white of an egg. It has been proved to be without taste or odour, and it is exceedingly difficult to hold, owing to its slippery nature.

Another family of mycetozoa is the Trichia Persimilis, which is found throughout the northern hemisphere. The eggs are yellow, and a group of them taken under the microscope, and thus enlarged for painting, suggests a plate of golden drop plums.

An entirely different variety of the mycetozoa family is the Stemonitis Splendens, easily one of the commonest and yet most beautiful forms to be seen. Instead of small balls on delicate stalks this has the appearance of a thick cluster of rushes, such as is often seen on the margin of a pool. It grows to a greater height than the majority of the mycetozoa, and now and then it is found to have reached

a height of quite an inch from its base. It delights in moisture, and without it does not thrive. A very powerful glass is needed for the examination of this beautiful growth if all the wonderful details are to be appreciated.

There are other varieties of mycetozoa which, again under the microscope, resemble nothing so much as tiny oranges. These will not to be found where the light is at all strong; indeed, it may be stated that the bulk of the mycetozoa family favour the shady confines of the marshland, where vegetable growth is both rank and free.

In America there are some varieties which rival the peacock in their hues, but these are rare and are not found in the Western States. Possibly what has been given will stir the microscopist to greater interest in these oft-neglected wonders of nature. Here we have been able to touch only the fringe of the subject. Remembering the 500 odd varieties this will be very apparent, so that there is a vast field for exploration and enjoyment.

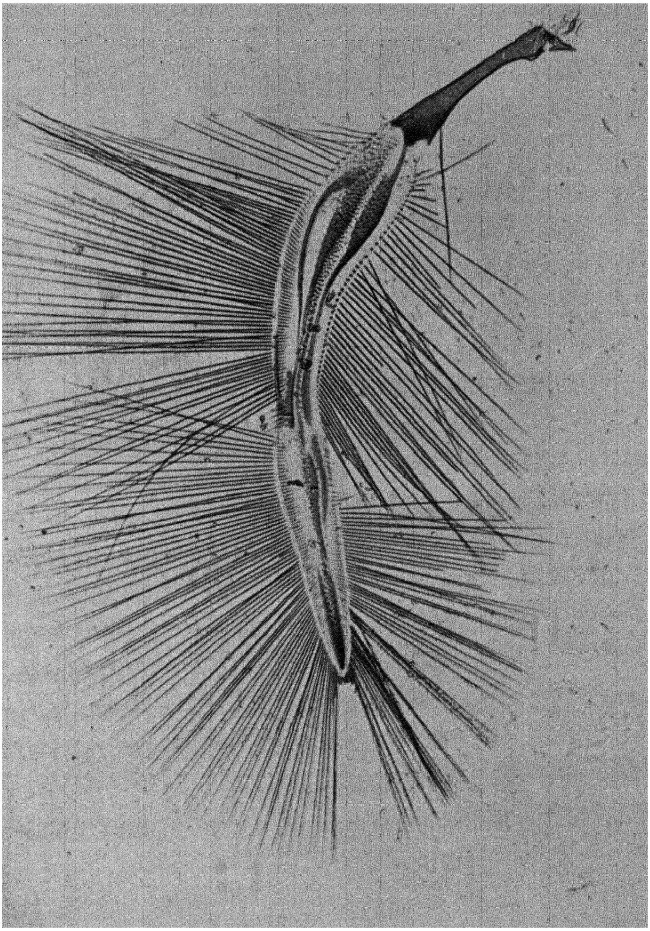
CHAPTER XVIII

THE MARVELS OF FROST AND SNOW

We all know how beautiful frost and snow can be, especially in the sunlight, but only the possessor of a magnifying glass, or better still, a microscope, can really appreciate how wonderful are the tiny crystals, which are practically invisible to the naked eye. Fortunately, or unfortunately, whichever way one regards winter's approach, the absence of snow in this country does not make the study of the snowflake practicable save in the more severe seasons. But when snow does come be sure to get the magnifying glass or the microscope at once. Few things are more fleeting than the snowflake, and only in the lowest of temperatures is it possible to examine it.

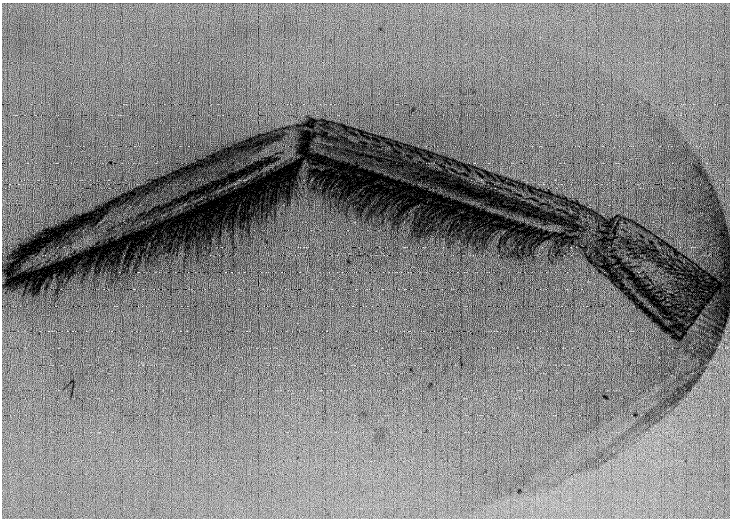
It is a good plan to spread a piece of black material, preferably velvet, in a position where the snowflake will fall upon it. The material should be placed upon a board also, in order that the snowflakes may be raised without disturbing them.

Under the magnifying glass a most remarkable and beautiful series of tiny plates and stars will be disclosed, far more intricate and exquisite than anything fashioned by human hands. The stars are of the six-ray type, whilst the plates will be found to have six sides also. Having discovered this new

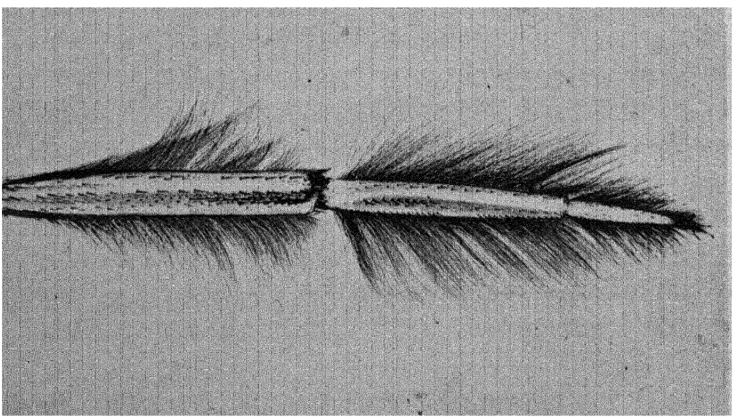


Wing of Fairy Beetle

[Face page 174



PADDLE OF WATER BUG × 10



PADDLE OF WATER BOATMAN × 10

Face page 175]

wonder of nature, the next thought almost certain to arise is, "Why are they shaped in this hexagonal fashion, and why are they in clusters?" To get the answer to such a question we must trace the snowflake in its journey from the clouds to the black material on which it rests. When the crystals make their start upon their journey through the air, they are quite detached, each crystal an entity, each so light that it seems to float like the tiniest of feathers in the air. They come about through the condensation which is constantly taking place amongst the clouds. Though formed of water vapour we might really consider them as small particles of cloud which have become detached, and are now intent on finding a resting place somewhere and somehow.

The intense cold of the upper regions of the atmosphere makes them frozen particles at the outset, and in this form they begin their journey to the ground, gathering, as they go, many a friend, joining hands, as it were, to become at last the snowflake, which may be quite small, or even a fairly large mass. There seems to be some law of nature which governs the whole process, a law which ensures that every crystal and plate must have its six sides. Thousands have been put under the microscope for photographic purposes; never has one been found to deviate from the general plan.

The art of photo-micrography—viz., photographs taken by the aid of the microscope—has revealed a most remarkable feature in the snow crystals; it is

that they form most perfect geometrical designs. Much was known before the microscope and the camera came to the aid of the observer, but the latest results attained are beyond anything that the boldest artist had ever endeavoured to portray. Whilst the crystals are all inevitably six-sided, they display an astounding variety of shape and design. Curiously, many of them resemble very closely geometrical designs which have been employed by artists for decorative painting, by artists in china for the embellishment of plates, and by ceiling artists, too, who have gone to great pains in order to get a proper setting for an elaborate chandelier. Again, many an artist in cut glassware has embodied in his well thought out design something which nature had done countless years before, but which man has discovered fully in quite a recent period. Again, many a lady is wearing a diamond ornament which might easily have been copied from the marvellous snow crystal.

Photo-micrography is not easy to undertake with successful results; the main difficulty, for instance, in photographing snow crystals is getting a perfectly dark background against which they will show up plainly. Experts have turned out some exceedingly clever work in this direction by the use of a compound microscope of great power, which has been fitted with a special condenser. The latter will produce a dark field illumination against which the white crystals will show up very clearly.

Coming now to ice—here the work of examination under the microscope or by hand-glass is easier,

mainly because frost takes so many forms, and whatever the snowfall of a winter may be, there will always be some frost. Hoar frost is probably more easy to obtain than any other kind, and it does not need the presence of water. Every lawn or piece of grass, besides most plant life, will give us the necessary crystals for examination. Instead of the six-sided crystal we have the extremely delicate silvery needles, which are often very much longer in the early spring than in mid-winter; contrary to what one would at first suppose. There is a simple reason for this; it is that the grass particularly, and some of the plants, have begun their growth. The needles should be carefully examined, and it will be found easier to do this with the hand-glass than with the microscope.

The frost that covers a pond begins with a series of needles which lie horizontally upon the water. If the process of freezing over is watched carefully, it will be seen that the ice needles begin at the margin of the pond, and then spread towards the middle, after which the surface of the pond appears to have a complete, but very thin coating of ice. There is, of course, a good reason for this procedure of Dame Nature. Bathers know that the water retains its heat long after the hot summer days have passed, and that even in November it will be warmer in the river than on the bank. Thus the land cools down more rapidly than the water; the cooling of the land allows frost to begin work at the margin, and so it goes on pushing out those beautiful tentacles until those which begin at the

right bank meet those from the left, as nearly as possible in the centre of the stretch of water.

The hand-glass is useful again to examine more minutely that wondrous array of fern leaves which are found upon the bedroom windows after a night of keen frost. The glass will show that the general make-up of the details of the design differ only slightly, whilst the general effect is vastly different. Thus, on some windows, the fern design will consist of many stems bearing close fronds, so close, indeed, that nothing can be seen through the glass. Perhaps in the next room the whole effect is much lighter, with vacant spaces through which the garden beyond may be seen. What is the reason for this difference in two rooms, both facing the same direction? The answer is that the moisture in the air of the two rooms will show some variation, possibly due to the number of people sleeping in one room as compared with the other. The whole effect is due to condensation within the room, coupled with a fairly severe frost outside. Thus, moisture running down the inside of the window will take various courses, and these will be transformed into the beautiful ferns which have puzzled the youthful mind from time immemorial. Have we not all asked the question, and received the reply, that the work was from the hand of that elusive gentleman rejoicing in the name of Jack Frost?

The writer well remembers the sequel to the answer given to his inquiry. A few days afterwards he was introduced to a young man visiting the house who was at first addressed as Mr. Frost, and

then more familiarly as Jack. Putting two and two together it seemed to my mind that here, indeed, was the gentleman whose artistry had both interested and slightly worried me. So he was asked how he did it, but somehow he gave a most unsatisfactory explanation, and I came to the conclusion that he had reasons of his own for keeping his nocturnal work a dead secret.

Whilst the general designs on the window are clearly of the fern type, one cannot help but notice that other feathery foliage is often present. At one time I thought that, in some remarkable way, the frost had photographed upon the window some of the foliage which was growing in the garden. This was after I learned that the human Jack Frost had nothing to do with my window.

Again, these designs are often representative of tropical shrubs and trees, which leads one off again on all kinds of possible theories. Actually, however, the magnifying glass dispels all our fancies, and brings the matter down to this—that the whole of these wondrous designs are really due to the way the frost needles come together, or fall apart. But we would rather think that Dame Nature is showing us still another way in which she can mystify and yet delight us.

Rime is often mistaken for hoar frost, but its origin is entirely different. Really, the rime is due to fog, especially when the fog follows quickly on the heels of a heavy frost of some days before. The frost may have passed on—or off, whichever we may choose—leaving behind a spell of intensely

cold weather, so cold that we may suspect frost, even if the experts tell us there is none. The fog comes, consisting of tiny droplets of moisture; these will become frozen when they come into contact with very cold surfaces, such as iron or wooden railings. Thus comes the rime, which offers, perhaps, little to the hand-glass and none to the microscope, but it is necessary that we should know the various kinds of frost.

It sometimes happens that a very sudden change of weather will take place—the wind, for instance, changing from the north to the south-west. Almost certainly rain will follow and then the trees, plants, and, indeed, anything out of doors, will take on a coating of beautiful crystal.

Even the high road—particularly in the country—will exhibit the wonders of frost and snow to the careful observer. Some exceedingly beautiful patterns are traced upon the road which has possessed some tiny water pools before a sudden onset of frost. Possibly the frost is succeeded by a cold nor' easter. Then watch carefully what happens to the road pool, and there again we may see the foliage and the ferns which were first observed upon the window pane.

Still another wonder of frost and snow, best examined through a magnifying glass, but beautiful enough without that aid, are the ice flowers. These are really very wonderful, and will well repay a careful examination. But they are not so frequently come across in Britain as some of the other marvels of frost and snow with which we have dealt. A

combination of events have to be found to give us good examples of ice flowers, and they are more prevalent in continental countries than in Britain. Those whose good fortune enables them to visit the lakes of Switzerland for the winter sports will be very familiar with these examples of Nature's fascinating handiwork. There is some doubt as to how they are really caused, but the general opinion would seem to be that they are the result of a change of atmosphere on the surface of the ice.

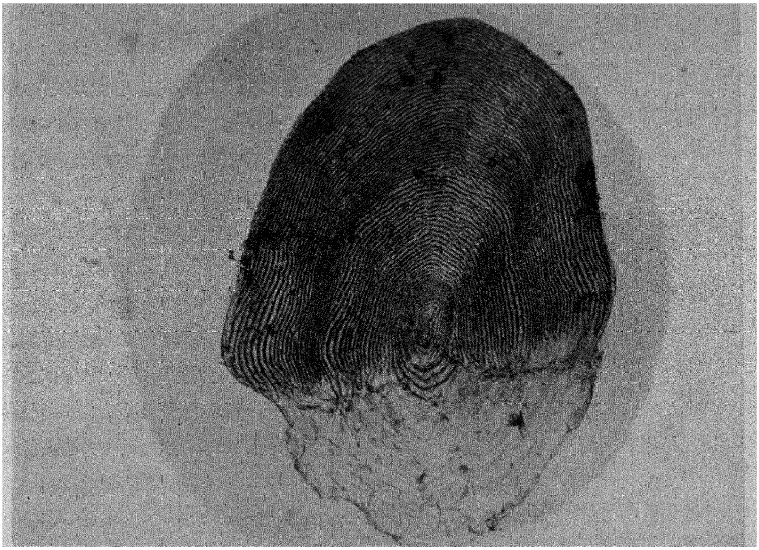
A sudden thaw followed by a frost has been found to produce quite a crop of these delicate flowers. Without any apparent reason a small rosette of crystals appears on the black, smooth surface of the ice; these grow steadily (though sometimes rapid growth has been observed), and they seem to expand outwards, forming delicate petals which make them so flower-like.

Some of the lakes, before the advent of the skaters in the early morning, have been perfect pictures with these feathery flowers of ice. Many of them have been examined under the hand-glass and the ice needles so common in the ordinary stretches of ice are seen to be present, and they are arranged in much the same way as the more delicate fern fronds upon the window pane. But whilst these are necessarily flat, the ice flowers are like their name, and some form beautiful little bouquets such as a woman might wear with advantage.

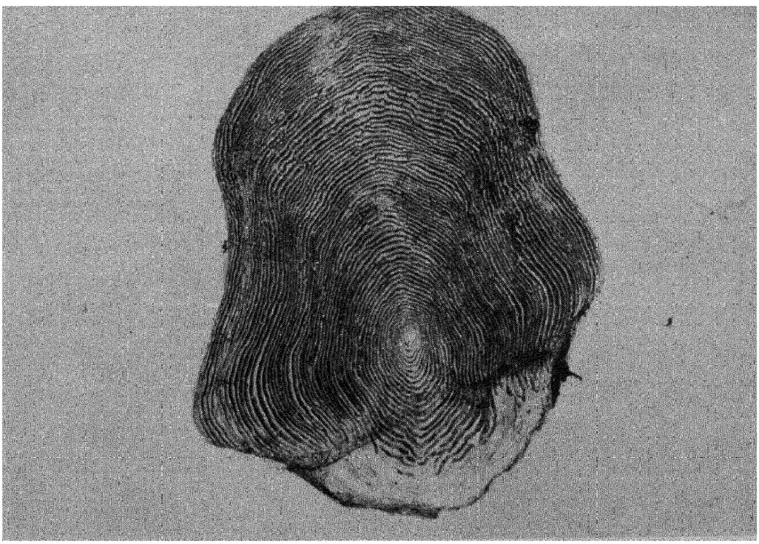
As already mentioned, these will be found, though not so frequently, upon English waters, and they are particularly noticeable on ponds which have

not been disturbed by the skater or slider. The best examples will usually be found where there are twigs or branches of sunken trees poking their heads through the ice.

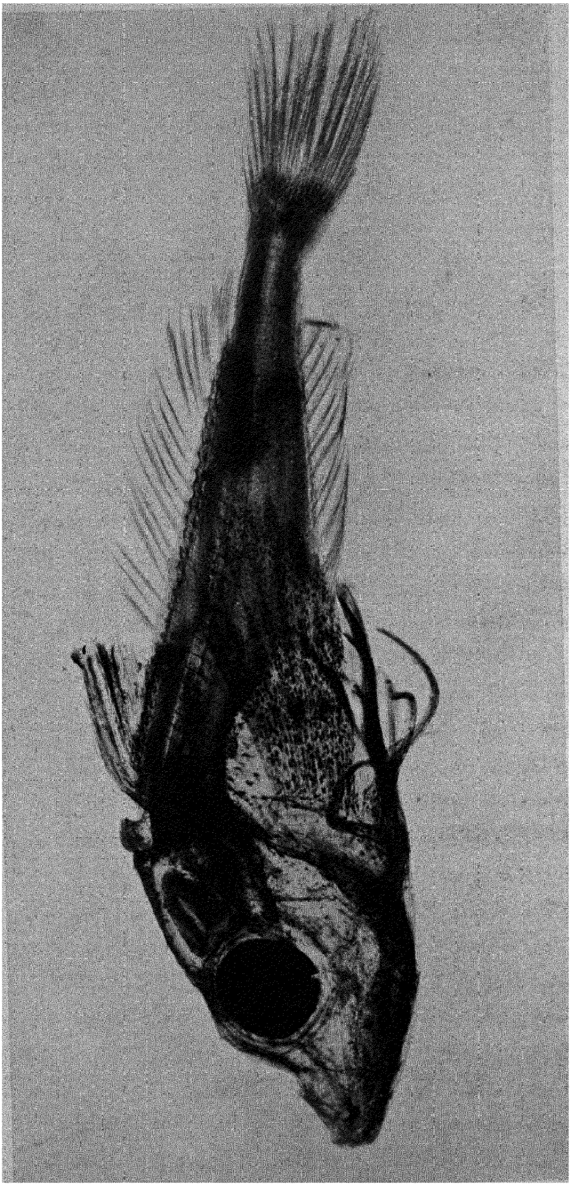
One more example of nature's work in frosty weather may be quoted, and this, fortunately, is frequently seen where a pond or lake, or the margins of a river, are covered with ice. These are the delicate white needles of the hoar frost which seem to take an especial delight in transforming prosaic reeds into the most wonderful and fairylike flowers. The effect is often very remarkable, and occasionally one is struck with the resemblance borne to a huge sponge. Again the full beauty of the crystals, which form this rich array, can best be examined with the aid of the pocket magnifying glass.



Scale of 3-year Salmon



Scale of 4-year Salmon [Face page 182



YOUNG GURNET

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CHAPTER XIX

THE MARVELS OF SEED GERMINATION

IT IS well worth while including in our examination of minute things the germination of seeds. Here is a source of the greatest interest, and certainly there is nothing more wonderful to put under the lens of the microscope. Not only seeds, but all kinds of living—and dead—plant growth will serve their turn, and give us some of the most enjoyable hours imaginable.

Quite a number of members of the vegetable world are indeed visible only under the microscope, and these, as far as possible, must certainly be included in our researches. These growths, which are so minute, have a most rapid rate of reproduction, and were there not enemies in the shape of man, animals, and even other plant life to deter them, it is possible that they would advance to such an extent that, like the giant weeds of the tropics, they would make other life impracticable. It is a fact that in certain parts of the world the rapid growth of weed pests makes it easier for the natives to clear a fresh section of forest land than to put up a fight against this unique force of nature.

Green is an almost universal colour in plant life, though there are many growths without it, especially

the fungi. To get to know more about the green pigment, which is so universal, scientists have found that it can be separated from the plant by using alcohol, thus obtaining a solution in which the colour is taken entirely from the plant and remains in the alcohol. We need not go to this trouble if we possess a microscope. If we take almost any leaf and study it closely under the lens, we shall observe that there are an immense number of very minute oval bodies; these, we shall find consist of very small portions of what is called the physical basis of life, which scientists name protoplasms. These are coloured by that wonderful substance called chlorophyll. The scientist will tell us that when the sun's rays reach the leaf some of the valuable rays will be absorbed by it, whilst the rest will be allowed to pass out on the other side. We might almost consider the leaf a door-keeper for the ray, which must pay something to pass on through the green door.

Why does the leaf take toll of the sun's ray? The answer is quite simple if you will think for a moment that the leaf is really the lung of the tree or plant. That glorious ray is the very breath of life, and what the leaf takes from the sun it passes on at once to provide the energy for further growth. We have already noted that the microscope shows that the leaf is made up of living cells; these are at work, in their unobtrusive fashion, to produce a series of chemical changes which are one of the greatest marvels of nature. In point of fact, two of our best known foods are produced forthwith by the chemical action indicated; these are sugar and starch. We

must not think of the starch in this case as the commercial substance sold for stiffening collars, nor yet of the sugar as resembling those snow-white lumps in the sugar basin. But the basis is the same.

With the aid of the microscope both the starch and the sugar can be detected, but only the skilled observer may detect the latter, whilst the starch is clearly visible under the lens, appearing in the shape of extremely minute, but still very definite grains.

We may take the chemist's analysis without bothering to make it ourselves, and agree that both sugar and starch contain three very important constituents —hydrogen, oxygen and carbon. The plants need the very thing that humans want to get rid of—carbon dioxide—and, having secured it, they break it up, retaining the carbon from the gas which is so harmful to humans. From it they build up the sugar and starch, and it is one of the marvels of nature that the plant can do all this quite easily, whilst if the scientist attempts it he must first obtain a very high temperature. It is the chlorophyll that enables the plant to beat the professor.

We have watched this remarkable green substance under the microscope. Now turn for a moment from the instrument, shut your eyes, and follow through some of the remarkable sequences in the world of nature, all arising from this delicate working out in miniature of the greatest scheme which we really can think of. The green plant—grass or

vegetable—becomes our food, either via the cow or directly via the saucepan in the case of grass and vegetables considered respectively. Because of our food we live and accomplish the wonders which man has been allowed to accomplish, such as the building of a great cathedral, a bridge, a city, a ship, a train, or, indeed, anything which is made by men's hands. If all green stuff were to die to-morrow, how long could we live? No one can say, but a complete cessation of growth would, in a few months, wipe out the whole of the human race, according to one authority, who points out as proof of this that the sailors of the old sailing ship days died like flies on long voyages simply because they were denied green food.

Further, we think of the wonders of machinery and the great and beneficent power developed on our behalf by steam. But what is steam? It is a gas produced by boiling water, and the water is boiled by coal or oil. What is coal but the sun's energy transmitted to plant life, via the means we have indicated, stored up for countless centuries, and then brought to the surface for our use by men whose efforts still depend upon the food produced by the earth. If they live mainly on meat, it is still meat that has come from the earth via the green grass. Then oil is believed to be caused by the sun's rays, though perhaps not directly through plant life as in the case of coal. Even so, some experiments have shown that oil can be obtained from seaweed, much of it containing that mysterious chlorophyll.

Now we may open our eyes and get ready fo another object for our microscope—the acorn. Bu a good deal has happened here before we can hop to bring the microscope to bear—that is the ordinar microscope. Let us consider how the acorn has com to its present size, remembering that though it i the seed of the mighty oak, from which another wil certainly grow if nature is allowed her way, th beginning of the acorn is some distance back. Th oak tree has two kinds of flowers—male and female The former are the catkins, which are very conspicu ous, whilst the female flowers seem to hide them selves very modestly amongst the foliage of th towering tree. When the time is opportune, and th pollen is ready for its work, the wind—another o nature's handmaidens—will blow the pollen from th catkins far and wide. Most of it is wasted. Natur seems to know this, and that is why she is so prodigal But some of the pollen, so fine in grain that we ma miss it entirely, will reach the female flower. Insid this flower there are some exceedingly small eggs— placed right at the centre. If the merest speck o pollen from the oak catkin can rest upon an egg the beginning of the next stage—the acorn—is accom plished. It is from this stage that we can hope t follow the growth of the oak by the acorn.

There is no harm in taking the fertilised flower from day to day, for the oak must always bear fa more of its graceful fruits than can ever be seeded i the ground. We shall note that the female flowe makes rather rapid growth to the acorn stage: Perhap the better plan would be not to pluck more than on

or two of varying size, but, with the hand magnifying glass, which will always be carried by the microscopist, a selected flower may be watched from day to day, and thus more easily the various stages will be followed until it is possible to take the well-grown acorn. Now comes the dissection of this wonder, and it will depend on how carefully you accomplish your task how much you will see. Assuming that the acorn is well developed, and that the dissection has been well done, this is what we shall be able to see. First a miniature axis, which will most certainly become the stem of the tree, with the root at its base, then there will be disclosed two objects which will be rather baffling to the observer unless he or she knows something of botany. These are called the seed-leaves, otherwise the cotyledons. These contain the starch upon which the infant tree must live until it has got a good start in life, just as the egg of the fowl is stored with rich food for the embryo chick.

There is not much more for the microscopist with the acorn unless it is put into the ground. We suggest that twenty should be gathered from the ground where they lie, and all be planted in a row. Then every three days an acorn may be lifted and the growth seen under the microscope; in all probability it will be impossible to put the seed back again, because you will almost certainly want to dissect it, and that means death to the acorn. But there are so many of them, in a normal season, that you need not have the usual compunction that all nature lovers must feel in destroying something which they cannot

make. The fate of millions of acorns is decided each year, and supposing each one that fell could grow, there would be no room for humans or animals upon our English countryside, so generous is the oak. Those acorns which are allowed to lie upon the ground appear lifeless; it is only the microscope which will show very clearly that latent and wonderful force which needs only the covering of the kindly soil to start it into the most amazing growth which one can imagine.

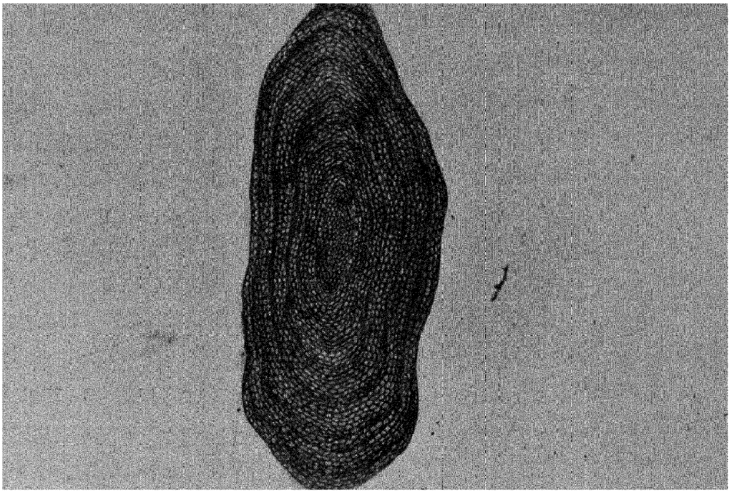
Stand beneath the stately oak with his vast trunk, its wide-spreading branches and then realise, if you can, that one day, when perhaps Queen Elizabeth was a little girl, some hand planted an acorn, or perhaps it fell unheeded, and was allowed to follow its own wishes. Here is the oak; there, at your feet, is the acorn—consider this miracle that nature is always attempting to perform. But you will never consider it properly unless you have the trained eye and the magnifying glass which is the open sesame to the microscopist.

Now back to our twenty acorns. If the ground is dry with lack of rain, the soil hard and unfavourable, scarcely any change will be detected upon cutting open that soft and beautifully formed shell—or husk. Shell sounds better, for the outer coat is indeed very beautiful, and do not forget to put a section under your glass. But if nature is in a more pleasant mood, and soft rain has been followed by warmth, plus a kindly soil, then the embryo oak is already striving to burst its bonds, responding to that call which all living things must respond to. Three more days and acorn

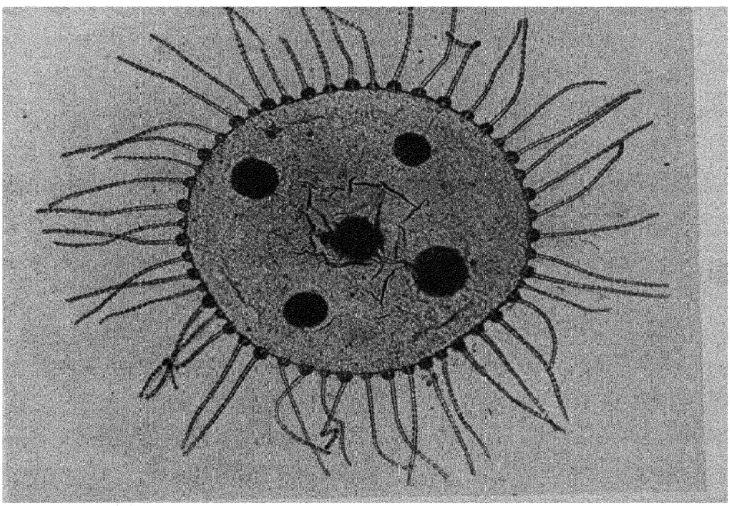
No 2 is lifted for examination; almost certainly we shall find that the shell has burst open, and that a beautifully proportioned shoot has either appeared, or, if circumstances are exceptionally favourable, has actually begun its business in life.

This is the root of the oak tree in its embryo form. Examine it carefully with your hand-glass, or, better still, upon a slide of the microscope. You may place the acorn back again, remembering its position, but it is suggested that the same seed should not be disturbed again and again, because, naturally enough, you will not be able to see the developments as they occur. Every lifting retards seriously the growth; in nearly all cases some damage must occur, and you will undoubtedly want to use the dissecting tools, so that the interior of the acorn may be exposed, to note the rapid development of the seed. If dissection is undertaken the acorn must be thrown away, of course.

But watch this second acorn carefully at the top end; almost certainly the other end of the axis is moving too—upwards and outwards—towards the light of day, whilst the tiny root is digging itself in away from the light. If this upper end of the axis is not seen in the second acorn it will most probably be quite apparent in the third, which, we shall remember, has been under the ground nine days. It is difficult to lay down any day-to-day rules of progress, because in no two cases will all the circumstances be similar, and quite a difference is made in the growth of plants, trees, and flowers by the situation of the county in which they are planted, possibly

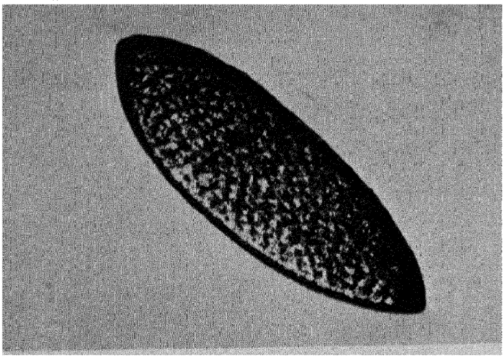


SCALE OF EEL ×14

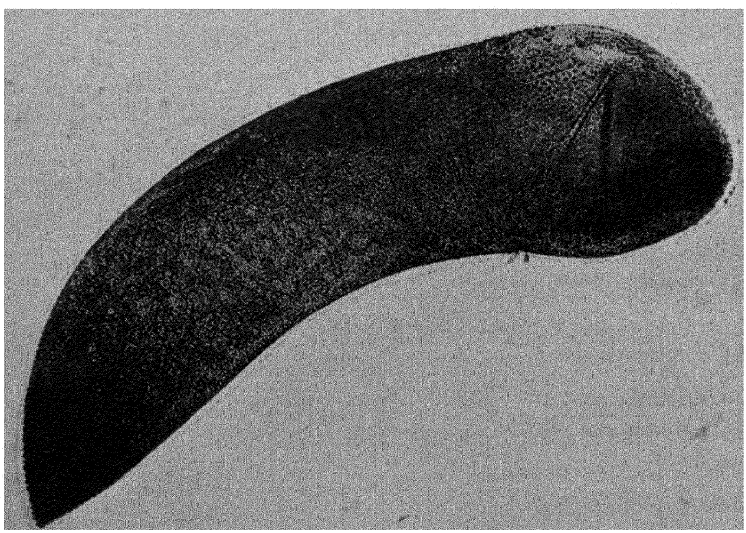


HYDROZOA ×35
Low form of marine life

[*Face page* 190



MOSQUITO EGG ×70
May be found in stagnant pools.



ANOTHER FORM OF MOSQUITO EGG

on the same day. Nor is it necessary to stipulate the position of the county really.

The writer knows a spot in Surrey which is never really very cold, and in spring it gets every bit of sunlight that is going. There is an old garden wall, under which most plants thrive in a truly wonderful way. The gardener at the house is able to show flowers and fruit bushes in bloom a clear fortnight before his more experienced colleague at the big house on the hill not half a mile away. Obviously, then, the acorns would make far more rapid progress in the garden at the foot of the hill, under that sunny wall, than if planted at the top; therefore we stress that the progress which is here indicated will not be uniform throughout the country.

Probably on the twelfth day, when you go for acorn No. 4, you will have no difficulty in finding it, for it and its remaining fellows will be showing a tiny shoot. Lifting it, you will be amazed at the growth made by the root, which has already got a good grip of the soil. Note particularly under your glass that very vital changes have been made in this root. Now turn to the other axis of the acorn, and you will observe that there is no vestige of green, which means that so far the acorn is not making progress in life directly from the beneficent rays of the sun; instead it is living on the stored-up energy (which, of course, came originally from the sun), found in the thick seed-leaves already mentioned. So does the microscope reveal this most wonderful working of Dame Nature.

We have seen the tiny oak tree at birth, and now without any further advice on the subject, you may follow the rest of the acorns in their development, noting as you do so that when the green leaves come out on the tiny tree a corresponding development takes place underground, the roots throwing out fresh feelers. These not only supply the growing tree with moisture, but they serve to anchor it so that when the wind sweeps the ground, the sturdy little tree may not fail to withstand it, but more particularly with regard to future needs rather than present, because, for some years, the oak tree will be a diminutive fellow. Lift the acorns now at less frequent intervals, and examine the wonders of the roots, their delicacy, their strength, and their careful spreading out to fufil the purposes indicated. You may transplant the tiny trees after lifting and examination to a spot where they can be left to grow under your own eye. It will not seriously damage them if you snip off one branch of the roots, but leave the top branches with the leaves.

If you need a delicate leaf, then get it from a young, but well-established tree. The wonder of the oak, which we have followed closely by the microscope, is the steady progress which is made under our eye. Everything about the evolution is so carefully balanced; the greater the branches above, the larger the number of roots below. The trunk is the communication between the two sections. Moisture is brought up from the ground via the trunk to supply the leaves with their needs; the leaves, having received their moisture, increase in number and size,

and feed upon the sunlight to bring the food to the trunk and to the roots. And so the tiny acorn grows to the great tree which, in time, will add both beauty and majesty to an English woodland, whilst, when the time comes, it will give one of the finest and most lasting timbers for manifold uses—all from the tiny acorn!

There is still one point which we should mention about the acorn. It is that we have assumed that the twenty were planted right side up. But make experiments in your planting—put some of them in flat, or in any position you like; it does not matter in the least to the acorn, it will adjust itself quite easily. If the acorn is placed in an horizontal position the shoots will take a neat curve upwards and downwards respectively. Some scientists say that the force of gravity has a lot to do with this.

Another remarkable factor about these shoots of the acorn, (and the experiments have been made with other seeds, having similar methods of rooting), is that the shoots seem to possess a sense of direction. But—and here is the truly remarkable factor—if the tip of the shoot is cut off, that sense of direction vanishes; that is to say, no longer does the shoot thrust itself downwards, if a root shoot, nor upwards if a stem shoot. One would almost think that plants and trees possessed brains; perhaps they do, but the microscope will not help us here.

It is possible—and very desirable—to grow many seeds in water, and then watch with a hand-glass the marvellous changes which take place day by day. To enable this to be done small bulb glasses can be

used, placed in a window. Much knowledge and great interest is a sequence to these experiments.

Much of what has been written of the acorn, which was chosen as an easy example to follow, is also true of other seeds. Try experiments with beans, peas, and various kinds of corn. They will prove most interesting subjects, both for the hand-glass and for the microscope.

CHAPTER XX

WORMS FOR THE MICROSCOPE

At first sight, the worm does not appear to be a very attractive specimen to bring to the microscope. In point of fact, however, the family will prove one of the most interesting, if we attempt its story. They have this advantage, that they may be found everywhere. Whilst the land worm, such as is found in the garden, taken as a family, will not be so interesting as those discovered in ponds or rock-pools, they will need our attention.

For the moment, let us consider the worms which will be found in water. The lowest form of the group are known as Planarians. All of them are small, but as between the fresh and salt water kinds there is this difference; whilst those found in ponds amongst the water-weed are usually elongated, the sea-water Planarians are better described as leaf-like. Both sections seem to feel no inconvenience if they are cut in two, since each part goes on living, and in time a new portion, this an exact replica of that cut away, will grow on to the section where the cut was made.

The next stage upwards in the worm family are known as Flukes, which are parasitic. While some of them exist on the skin of their hosts, others will be found in the intestines.

The life story of the common Liver-Flukes has been quoted as an excellent example of the development of these strange creatures. They are born in the bodies of sheep, later escaping therefrom. Their next stage is a free-swimming life in water. If they survive from attacks of enemies in the water, they search for water-snails and bore their way into their hapless bodies. Within the bodies of their hosts, they multiply exceedingly, and their next stage is a complete change. They become in effect, a very miniature tadpole, they then forsake the water, and in this strange circle of Nature's working, having reached land, the tadpoles will most probably be eaten by sheep. If so, the creature bores its way into the sheep's liver, and then comes that scourge of the farmer, which he calls rot.

Another stage upwards in the worm family, is the Tape-worm. These do not call for special notice because in effect, they resemble those with which we have still to deal.

Another stage is reached with the Ribbon-worm, whilst still another is known as the Thread-worm, of these the Horsehair is the best known type. There are quite a number of country folk who still believe it is nothing more or less than a horsehair which has, by some means become endowed with life. No explanation is vouchsafed to account for the transformation!

It will be difficult for the microscopist to obtain specimens of the worms already mentioned, but it is necessary that they should be included, in case an opportunity comes along to identify them by

means of the microscope. Identification will by no means be easy, but having given their origin and their locality, it may be possible to recognize them, if brought under the lens.

Next we come to what are termed the Annelids, better known as the True-worm. In these the body is divided into a number of minute rings, perhaps it would be better to call them segments. Without the microscope these can be seen quite easily by taking a worm from the garden and placing it either upon a plate or upon the hand. What the eye will not see, however, is the remarkable series of bristles which appear on each ring, and are believed to be the means by which the worm progresses.

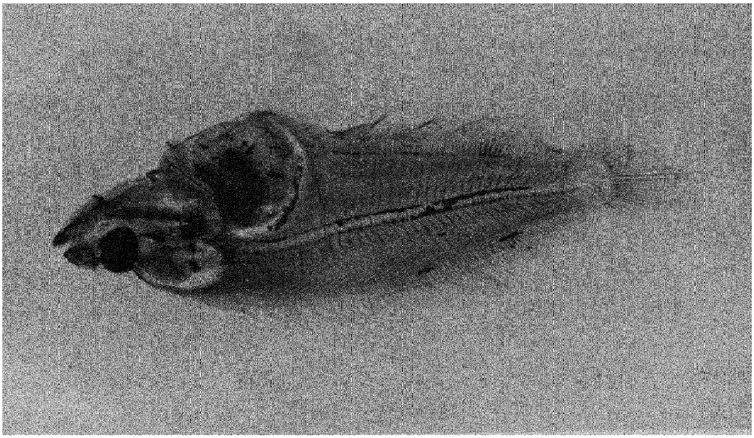
In the summer time the observer along the banks of a stream will often note a discolouration of the water, and he may not know how it has arisen. In many cases it is due entirely to the Summer-worm, often called by the country people the River-worm.

These little fellows burrow in the mud with their heads downwards, their tails may be seen projecting in the water and waving to and fro. It will be noticed, particularly if one can be brought to the bank and examined under the hand-glass, that the skin is quite transparent, but it has a ruddy colour, which is due entirely to the blood showing through it. Examine carefully with the hand-glass, and if possible, bring one home for further examination under the microscope. In either case the segments will be noticed, and they may be counted;

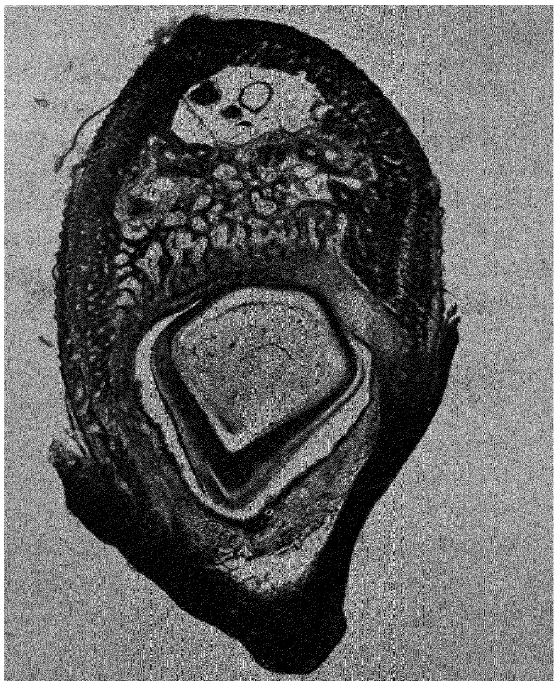
particularly the bristles upon each should be observed.

Another worm, which is met with in practically every pond, is known as the common Naïs. In most cases if a net is used for exploratory purposes, the Naïs will almost certainly be caught in it; in any case it will be found on the water-weeds. These curious little creatures prefer animal to vegetable food, and hardly any insect in the pond is safe from them. They have a long proboscis, and also spines which project on each side of the body, going far beyond the bundles of bristles which seem to grow upon most of the segments.

These small creatures have a particular interest for the naturalist and the microscopist, since they multiply in a most curious way; the naturalist calls it propagation by budding. The first stage is when a bud appears between two segments, usually near the middle of the body. If only this process can be followed under the microscope, one of the greatest wonders of Nature will be observed. The bud not only becomes a worm, but the head portion of the parent grows a new tail, and the other end, the tail portion, grows a new head. The result is, that before the bud secures its freedom, others are thrown out from the skin of the worm that originally budded, and the net result is that before any separation takes place, a remarkable chain of worms is linked together, and they all secure their nourishment by means of the mouth of the worm which first produced the buds.

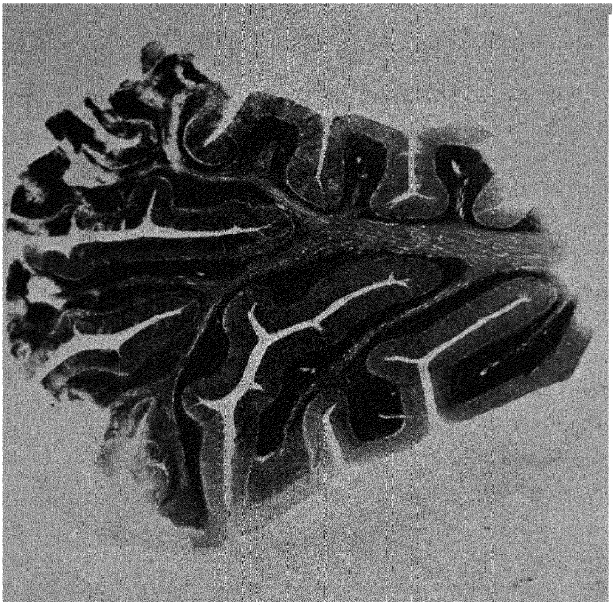


YOUNG DAB $\times 6$

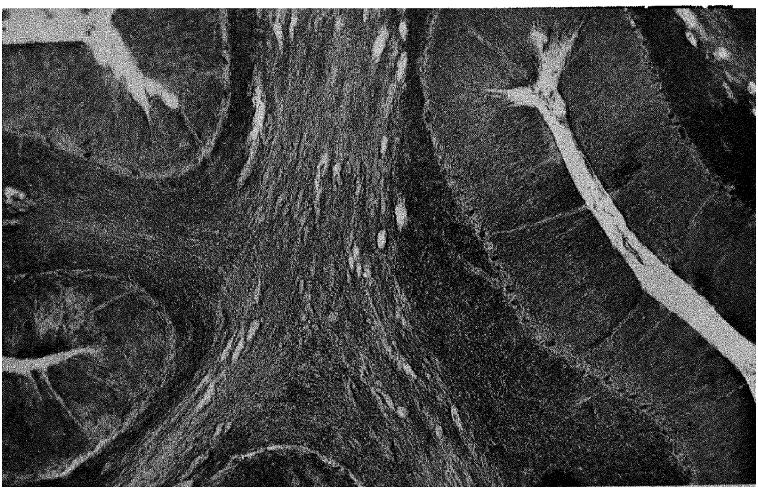


SECTION THROUGH JAW OF A KITTEN

[*Face page* 198



SECTION OF HUMAN BRAIN (*Cerebellum*) $\times 9$



A SECTION OF THE HUMAN BRAIN $\times 35$

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There are two groups into which the True-worms are divided; the division is made by naturalists according to whether the bristles on the segments are numerous or sparse. Those with which we are now about to deal belong to the class which has many bristles.

In this class are found most of the Marine-worms; they are so numerous, and many of them so very beautiful, that it is difficult to make a choice either for the aquarium or for the microscope. Wherever a Marine Aquarium can be utilized, the microscopist has necessarily a very wide choice of objects, and at any time he can help himself. The smaller worms can be transferred quite easily to the live cage, but it may not be possible to do this with the larger variety.

From the point of view of the microscopist, the Tube-Dwellers are possibly the most interesting of the worms which will be found in sea water. They are called Tube-Dwellers because they live in remarkable structures which they have built up from the lime gathered from the sea water. In some cases grains of sand and very minute fragments of shell have been brought together by means of a glutinous secretion obtained from the body of the worm. Under the microscope the segments of these curious little creatures will be found to be of the greatest interest. Most of the segments are covered with tiny forests of bristles, and it is believed that the worms use these as a method of coming out from, and into their dwellings. They do not come out altogether; possibly if they did, they might not

be able to return. These curious little worms breathe through orifices, which are really a form of gills placed near the head. The young of the Tube-Dwellers are developed from eggs, and even at birth they have a decided resemblance to their parents.

The remarkably small spiral shell repays careful examination under the microscope. It will usually be found attached by one side to the fronds of the common Bladderwrack; in some cases they will also be found upon the stems of the coralline. Whilst the average person upon the seashore will pass the Bladderwrack and the Coralline with not more than a casual glance, the naturalist and the microscopist will almost certainly want to make a closer examination. One of the first things he will notice is that, particularly upon the coralline, there will be hundreds of these curious little worms.

The explorer of the seashore should look out for a suitable spray of coralline, noting whether it is studded or not with the Tube-Dwellers; if so, bring it along and try the experiment, with the microscope, of using a dark mount illumination, combined with a low power; the result will be a very remarkable picture of one of the minor beauties of the seashore.

To obtain a Tube-Dweller without breaking away its structure, leave one or two in a bottle of sea water for a few days; if the bottle is then shaken the chances are that one or more of the worms will be dislodged, and both tube and worm can be examined separately, and in their entirety.

Another curious tube maker is known as the *Othonia Gracilis;* there is a marked difference between these and the type already dealt with; the difference lies in the tube, which is perfectly straight instead of being spiral. In addition, it is constituted of mud which is lined with very fine membraneous skin. This curious worm will be found very frequently upon the disc of the red seaweed. Its body is made up of thirteen rings, and under the microscope it will be found that the first and the last segments have each two eye-spots. There are also tentacles which are of a light straw colour, and they have a fair length.

An experiment has been suggested with regard to the Othonia Gracilis; the microscopist should, with his dissecting tools, take away the tube from one of the worms, and then, without having injured the inhabitant of the tube, drop it into a glass of clear sea water. It is desirable to place some weed and sand in the glass. By means of a magnifier, watch the worm in its endeavour to build a new tube. It will quickly discover that there is no mud, which is so important a feature in the building of the tube. It would appear as if the quaint little creature quickly discovered the absence of mud, and then tried to use the sand, but this will not do, and it will probably live for some days or even weeks without its usual home. Meanwhile, it can be studied day by day by means of the pocket-glass.

The great advantage of sea-worms is that, as a rule, they may be kept quite easily for some weeks, with very little attention to the water. They, there-

fore, offer themselves as very useful and interesting objects for the microscope. Some of them are very beautiful indeed, especially under the lens, and the unaided eye would never detect their remarkable colours.

Some owners of Marine Aquariums have stated that they have kept worms from rock-pools for months and years, and this they appear to be able to do without the animals suffering any great harm.

CHAPTER XXI

THE MARVELS OF INSECT AND PLANT LIFE

INSECTS prey upon plants, and, to a lesser degree, plants, as we shall shortly see, prey upon insects.

The garden will provide, only too freely, many an insect for the microscope.

Take a casual stroll down the path, especially in late spring, and look out for any kind of caterpillar that may be doing its utmost to demolish a cabbage. Bring him along and you need have no compunction in putting him to sleep for all time. Carefully dissect the pest, and then place the various objects you obtain upon a slide. Possibly the first object which will engage your interest, apart from the often beautiful colouring, will be the hairs. If you can manage to secure what is popularly called the tiger caterpillar, one of the largest, do so. Here the hairs appear like a barbed stake under the microscope. These barbs will readily engage in the more tender portion of the hand, and they will be exceedingly painful in certain circumstances. The lens tells us why they can be so.

The common gnat is another garden habitant that we would rather be without, but it forms a fascinating study for the microscope, especially as it can be very easily dissected. The head should be placed upon a

slide first of all; observe at once the compound eye. No wonder the gnat can see his way about so well and detect so easily our presence for an appetising meal—this eye consists of a great number of tiny lenses, too numerous to count even under the microscope. It is one of the marvels of nature that each tiny lens is connected, by a minute membrane, with the optic nerve, and is thus capable of receiving its impressions. The common house-fly shares with the gnat this compound eye; indeed, many other tiny insects are thus equipped. It has been estimated that in the eye of the house-fly there are over 4,000 facets, which are the termination of the lenses, and are hexagonal in shape. It seems incredible, but it is true; what is more remarkable is that the cabbage-butterfly has something like 17,000!

There are other parts of the gnat which are well worth our special study; particularly is this true of the antennæ. These are really beautiful. The more one examines the smaller insects the more wonderful do they appear, so delicate, so strong, so light.

Sometimes a dead bee will be found; bring this at once to the microscope, for it is another of the most marvellous things in nature. The head should be specially examined, and if practice has been obtained in dissecting, it is well to tackle the breaking up of this tiny structure. The mouth, as one would imagine, is a most remarkable combination. The tiny tongue is seen to be covered with hairs if a high power is applied; here is the extractor of honey, a hard-working apparatus if ever there was one.

Although it will not be possible to see in Britain the best examples of plants which prey upon animal or insect life, yet it may be possible for some readers abroad to investigate very closely and easily the wonders of the carnivorous plants.

We are so accustomed to thinking of vegetable life as being expressly a growth for the food of man and beast, that it comes as something of a shock to find the reverse happening. Although the most remarkable examples of plants feeding upon insects are not found in Britain, it is worth noting that, of over four hundred known varieties, many of them are natives of this country.

Long before the naturalist would really admit the fact that life was carried on by the plant securing victims from the insect world, he rather suspected growths of having this curious attribute. What was once suspected is now generally admitted, and from time to time new plants are added to the imposing list of those which lay toll upon the winged and crawling insects that pass near or upon them.

When once the fact was established that certain inhabitants of the plant world were prone to a diet made up of animal life, the naturalist began to search for the reason, and here he joined hands with the botanist, who was equally interested in this apparent reversal of nature's usual method of procedure. One of the first discoveries was that, so far as could be ascertained, the insect-loving plant was never found in any but marshy ground.

Now came a very remarkable theory which was soon proved to be perfectly correct. It was that

swampy ground was lacking in nitrogen, owing to the acidity of the soil. The plants could not do without the nitrogen and so they looked round for something which would supply their need. Insects could supply the missing material, and so the next step was for the plants to adapt themselves, first to the capture of the insects, and then to devouring them. Whilst some authorities are of the opinion that it was not necessary for the plants to induce visitors to alight, as most winged creatures must and will do so, others contend that they laid themselves out to attract the creatures. Whatever happens the plants do not go short of food, and the way they secure it is one of the most wonderful processes of many in which Dame Nature delights.

Perhaps the most wonderful of these insect-trapping plants is the Dionæa, which is largely found in North Carolina, this State having what are called "pine barrens," curious, boggy land in which the plant thrives exceedingly, spreading itself wantonly in all directions as if in search of prey. It was in this part of the world that an Englishman, John Ellis, came to the conclusion that the leaves of the plant were traps for insects of the larger kind. He observed that the smaller insects, although they alighted freely upon the leaves, got clear away. Since the time of Ellis it has been suggested that the plant will not trouble about such small fry, as they contain little of the nitrogen which it so badly needs. This makes it appear that the plant can think; more reasonably we may suppose that the arrangement of the closing of the double leaf is either purposely, or accidentally

not tight enough to entrap the tiny insects whose food value is so slight.

A naturalist working on behalf of the American Museum of Natural History has furnished his employers with some extraordinary results in which the "bag" of fifty leaves of the Dionæa was carefully recorded, the victims being arranged for inspection. All kinds of large insects had found a prison in those curious leaves, including beetles, spiders, wasps, and even large ants, showing that it is not only the winged insects that fall a prey.

It was a long time—practically a century—before Ellis was proved right. When he had announced his theory he found that it was not acceptable to the naturalists of that period; even the great Linnæus could not bring himself to believe that the trapping of the insects was anything more than a purely accidental happening, especially as his own experiments seemed to show that many of the creatures got free, little the worse for their adventure. To test the theories of the two noted naturalists, others placed meat upon the leaves and watched patiently for results.

Again there was conflict of opinion, and so the point remained largely undetermined until the American botanist, Dr. Canby, had made long observation of the North Carolina plants. He found that a very great change went forward directly the insect was firmly in the grip of the closing leaf. The most important was that the purple glands of the plant began to exude a curious sticky liquid, which gradually dissolved all the softer portions of the insect's body

until it resembled the substance used for the purpose; this substance was then absorbed by the leaves, and it seemed clear that it was being utilized as a valuable food. Canby was able to show that the whole process varied with different plants, the period taking from a day or two to a fortnight. Whilst the leaf was closed the insects alighting upon it went freely to others which happened to be open, and thus escaped once, only to be caught later.

If the leaf of the Dionæa can be examined it will be found that its normal position is open, something like a spectacle-case which has not opened quite flat. The edges are surrounded by a series of spikes, and then there are what are called trigger hairs, whilst the inner surface forms a kind of pad upon which the sticky substance will be exuded when the fly has entered the trap, his entry being signalled to the brain of the plant (assuming for the nonce that a plant may have brains), by the trigger hairs. The first movement is quick, but the complete closing of the leaf net is slower, which enables the unwanted small insects to get free. When the leaves have finished their meal upon the unlucky wight that happened to walk upon a tempting expanse, they begin to open again.

The traveller along the Carolina coast, where the Dionæa are mainly found, will probably first detect the long tender spikes upon which are borne a cluster of whitish flowers; then he looks down towards the ground and there sees the leaves waiting, or perhaps enjoying their prey. Out comes the hand magnifying glass, and without disturbing the plants the

observer may watch this most remarkable process of nature's method of supplying the needs of the plant by animal life. More particularly will he observe that many insects seem to walk across the two lobes of the leaf without coming to any harm. But his glass will show clearly why this is so; it is that they are the smaller fry, and they can manage to cross the surface without touching three very delicate bristles which stand, sentinel fashion, in the centre of the leaf. Further, the observer will notice that whilst the small insect may easily avoid these bristles, the larger will almost certainly touch one or probably two of them. One is sufficient to release what may well be called a hair trigger, and, like the snap of a spectacle case, the wasp or other creature is at death's door.

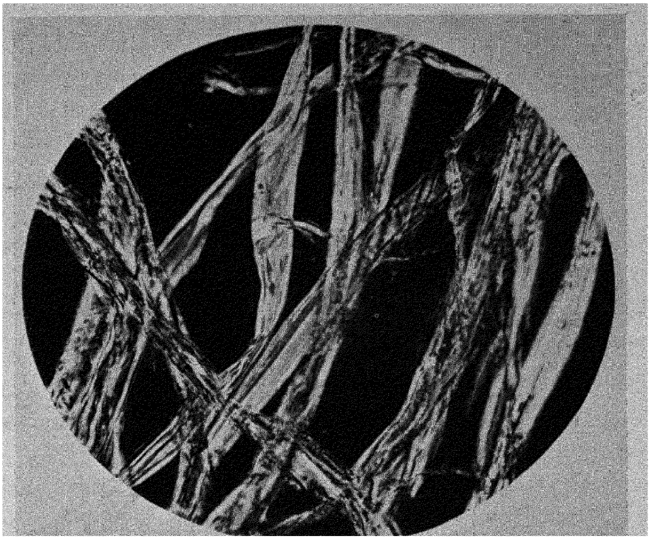
Darwin, the great naturalist, was intensely interested in these plants, which are known more frequently as Venus's Fly-trap than by the name we have used earlier. Darwin kept them under close observation in a greenhouse, but he was rather under the impression that what he saw was not the real life of the plant as it would be in its native haunts. When he heard about Dr. Canby's experiments he got into touch with him, and obtained information from the real home of the plant, all of which confirmed his own theories, though, in some respects, he had to alter some of them.

So much for the plant which is found in Carolina, where few of us are likely to find it. Now let us look at its counterpart in Britain, and actually there are a great number, coming under the general title

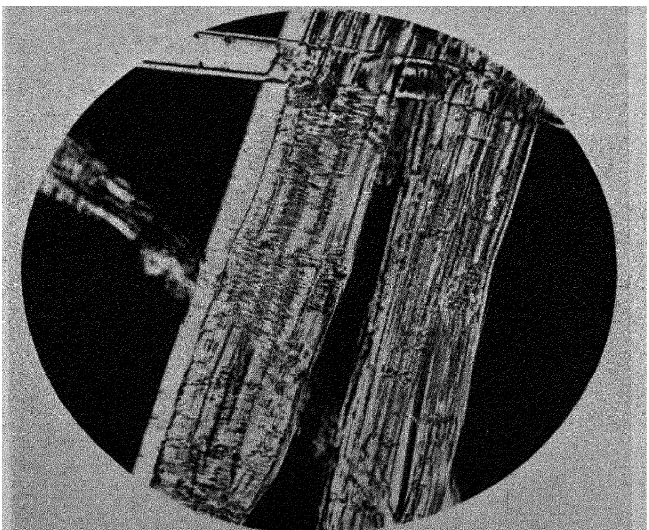
of Sundew. We must choose some marshland for our search, and most probably the first to be discovered will be the Round-leaved Sundew, which is the most prevalent. It follows its American cousin in some ways, notably that its leaves form a kind of rosette, lying on or close to the ground. The stalk is rather long and has a growth of hairs upon it, terminated by a round, blade-like leaf. There are many reddish-purple tentacles, and if you can find and gather one of these leaves, put it under the hand-glass or take it home for the microscope.

You will find that each tentacle has a gland at its termination, and the gland has what looks like a drop of water; actually, it is something which we might perhaps best describe as vegetable gum. Besides the long and very supple tentacles, there are others, much shorter, which appear to stud the upper surface of the leaves of the sundew.

You will most probably have been attracted to the round-leaved sundew by its colourful leaves, and if the sun is out it is almost sure to show up the tiny, clear globules. You may not be able to spend a sufficient time by the plant to watch what goes on, but quite easily you may bring home a leaf which is waiting for a victim and another which is fulfilling its destiny—that of feeding the plant upon insect life. Quite naturally insects, both winged and crawling, are attracted by the globules: they are singularly fascinating to a creature which must always explore everything which promises food or drink. Should a leg or a wing touch that



STRUCTURE OF HEMP



STRUCTURE OF COTTON

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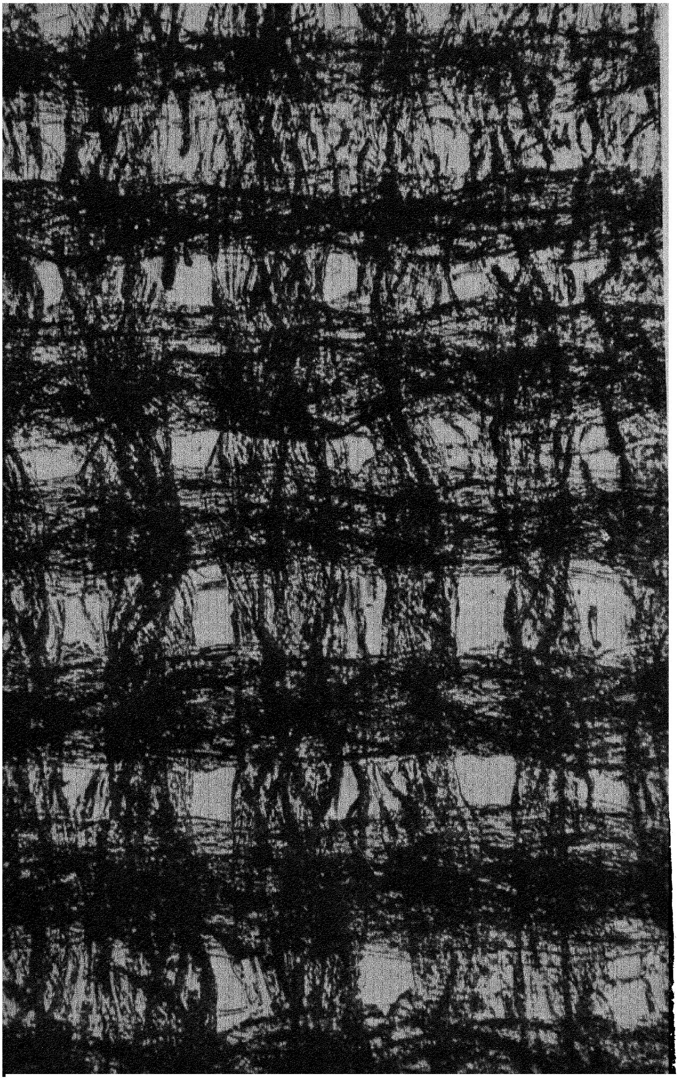

Structure of Fine Linen × 110

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gummy globule the chances are that the wanderer will wander no farther.

Now comes the miracle of the plant's effort for a food supply. The insect is held by the gum of the globule, but it struggles to get away. This struggling brings it into contact with some of the smaller tentacles most likely; in any case the messages are sent to the nerve centre, or brain, of the sundew and the reply is telegraphed back, "Secure the victim!" So it seems, anyhow. Instantly the other tentacles appear to bend over to secure the insect, and his fate is made certain by the margins of the leaf bending over, too, so the result is that the fly, or whatever insect there may be within the net, is fastened there beyond rescue. Then follows the process of breaking down the softer parts of the insect's body for food, the process being largely that followed by the Dionæa already described. With the microscope the process may be followed as far as possible, and certainly the hand-glass will show some of the greatest wonders of nature if brought to the spot where the sundew flourishes, and carries on its strange hunt for living creatures.

CHAPTER XXII

HINTS ON PHOTO-MICROGRAPHY

ALTHOUGH the majority of microscopists will be inclined to fight shy of Photo-Micrography, it is not really the difficult business that its long name suggests. In any case it is necessary that some details of the work shall be given, in order that our subject may be fully covered. Probably nine people out of ten would say, "Yes, I should like to undertake photo-micrography, but is it not a fact that I shall have to buy further costly apparatus, and that I shall have to be at constant expense for plates, and other details?" To this question, the answer would be that it is useless to pretend that photo-micrography can be undertaken without some expenditure for the apparatus. However, the work is not beyond the average person, but it would be useless attempting it unless this person had a good working knowledge of photography generally. If he is well up in camera work, and the subsequent development of his negatives, and has also made good use of his microscope, there is no reason at all, why he should not buy the simplest apparatus possible, and begin the work of producing satisfactory photo-micrographs.

The foregoing is especially true if the microscopist is prepared to content himself with low-

power photo-micrography. The real difficulty comes along when the enthusiast determines that he will use high-power. It would be useless him thinking that he could proceed at once from low-power photo-micrography to high-power; if done at all, the latter would have to be reached by easy stages.

Every user of the camera is well aware of the difficulty in deciding what exposure shall be given for any particular object; it is even more difficult to determine that exposure, especially if the object photographed is alive. Again, there is always the difficulty of determining how far the natural light will serve the photographer's purpose. Bearing all this in mind, it is suggested that the novice should not only begin with low-power work, but that he should choose only, for some time, fixed objects. If he is content to work on these lines, very satisfactory results may be attained after a few experiments.

It must be stressed here, particularly, that it is useless coming to the simplest forms of photo-micrography without having a thorough knowledge of the routine employed with a camera, and the subsequent developing and printing of the negatives obtained with it. Much, again, will depend upon the type of camera brought into use with the microscope; it is necessary that the camera should not be one of the cheaper variety; that is if really good results are to be attained. Perhaps the best camera for the purpose is one possessing a bellows; in this case, the lens of the camera is temporarily removed, then the microscope is placed with its object and

the camera in line. The camera is then fixed, and an exposure is made. Care is very necessary as regards the source of light, which must also be in line. That, briefly stated, is the beginning, but there are several details which must be carefully attended to, or otherwise the results will not be worth while.

One of the first details to be remembered, and to be stressed here, is that the body of the microscope must be inclined horizontally, whilst the eye-piece end of the microscope tube must be connected with the aperture of the camera. The very important consideration here is that the connection must be absolutely light-tight; the amateur photographer will have some little difficulty here perhaps, but the expert photographer will know that the best method of making the light-tight connection is by using a black velvet collar, which must be attached to the camera flange. The best method of adjustment is by means of elastic, which must be so arranged that it will hold firmly the tube of the microscope.

The novice will find another difficulty, which, however, he may easily surmount, in keeping the microscope and camera exactly in line. This may be best achieved by fixing on to the table or work-bench, two parallel sections of wood, which are kept perfectly straight; between them is fixed the camera and the microscope, perfectly in line, and so arranged that they cannot be moved.

If a good deal of work is to be undertaken in this connection, it is an extremely good plan to obtain a section of planed timber and fix permanently the two

parallel sections of wood upon it; the board, in this case, must be of ample size, for not only will the microscope and camera have to be fixed upon it, but there is also the lamp which must be placed in line with the objective and the centre of the focussing screen of the camera. It should be mentioned here that the mirror of the microscope is not necessary for this work; it may either be detached or turned aside.

The greatest difficulty which will have to be faced is to secure the perfect illumination of the object; on the whole, the worker will find that a metal filament opal or pearl electric lamp will give the best results; some experts recommend that the electric lamp should be placed in a box which has a whitewashed inside. It will be necessary to cut a square or round hole, with a diameter of about three inches, in the side of the box so that the light may escape; it is a good plan to get more contrast and to subdue slightly the light by a piece of coloured glass or a light filter. It is advised that too much light is not employed; some workers will find it a good plan to introduce a bulls-eye condenser; by its means the light can be parallelized. It will be necessary in this case to have the rays of light, the condenser, the object, and the microscope, all in perfect line.

Now to proceed to take a photograph; the object must be placed in position on the stage of the microscope, and it should be roughly focussed. The next step is to connect the tube of the microscope and the camera, bearing in mind that they must be perfectly in line; next see that the light is properly arranged,

so that it is possible to focus the image projected on to the focussing screen of the camera. In some cases it will be found that the image is not quite big enough to fill the screen, so if the bellows camera is being used, the bellows are extended, and further efforts are made until the size is found to be satisfactory. The next step is to insert the dark slide, and then the exposure is made. The worker will have to determine what this exposure will have to be, bearing in mind the degree of illumination, and the nature of the object and the speed of the plate. It is necessary to stress that only by experiment, which means probably the wasting of many plates, can the photographer progress to really satisfactory results. He will find that artificial light is always the best for photo-micrography, the reason for this is that artificial light can be assessed, and we know that it does not vary, but there are rarely two days when the same conditions of light are found.

It is difficult to say what plates will be most suitable for this work; experts are very divided on this point, and whilst some recommend fast plates, others insist that the best results can only be obtained with slow ones. Another point which it is necessary to stress, is that none of the apparatus must be moved whilst an exposure is made; but this advice is hardly necessary to the expert photographer who knows perfectly well that, except with snapshots, it is not possible to secure good work, if the camera is moved even the slightest during a time-exposure. If every microscopist will remember to keep perfectly still, he will avoid any trouble in this respect.

The hints given above, are only intended to assist the experimenter at the beginning of his work; if he is very anxious to go farther, it is extremely necessary that he should obtain a handbook upon Photo-Micrography. There are several upon the market, and some of them are quite cheap, and in any case they may be obtained through a second-hand bookshop. A simple and inexpensive self-contained photo-micrographic outfit made by F. Davidson & Co. is illustrated and can be recommended for those content with magnifications of X10, X20 and X30 only. Specimens can also be viewed by more than one person on the ground glass screen if the room is reasonably darkened.

CHAPTER XXIII

THE TELESCOPE

IT WAS once said that the telescope was the father of the microscope; in any case, it has the same attributes, and whilst its use is not quite that of the microscope, its make-up is very similar. It follows, therefore, that the story of the telescope has some direct relation to the evolution of the microscope.

In the long ago, when ancient astronomers were studying the heavens, they must have yearned for something which would help them to get a better knowledge of the celestial bodies. Whether they had any kind of telescope or not we do not know, but it is quite possible that they did have some such aid to their observations.

We are constantly reminded, by the discoveries in Arabia and Egypt, that a very high state of civilization existed some thousands of years ago, and it is far more likely that many of the instruments which we now use, were known then, and their secret subsequently lost, than that these civilised people were without what we now deem the necessaries of modern life.

Jumping some centuries to a point where we have some definite knowledge, we are told that Roger Bacon, a man far in advance of his time, was well

acquainted with the use of the magnifying glass. This was in the thirteenth century, so that we may fairly claim that the beginning of the English telescope may be placed about this period. It is quite possible that Bacon actually made a telescope; on the other hand, there is reason to think that had he possessed such an instrument, he would not have written some of his conjectures upon the celestial bodies. Some three hundred years later, Porta mentioned a method of joining two glasses in such a way "that the observer could see both remote and near objects larger than they otherwise appeared, and all very distinct."

Again, there is some doubt as to what Porta accomplished, and most historians place the invention of the telescope something like fifty years later than that recorded in Porta's *Magia Naturalis.* On the other hand, there is no doubt whatever that Leonard Digges had, by access to Roger Bacon's manuscript, improved on his magnifying glass, and he not only used it in the same way that the microscope is now used to-day, but also for observing distant objects.

With the opening of the seventeenth century, the introduction of the telescope was assured, since no fewer than three men—all of them Dutchmen, by the way—were working to produce a magnifying glass fitted to a tube by which the heavenly bodies could be observed. There is a capital story told of how one of them, Lippershey, made his first telescope, and, of the three Dutchmen, his name is more frequently mentioned as the originator of the

telescope: the others, by the way, were Zacharias, Jansen, and James Metius, the latter was a native of Alkmaar, whilst Jansen and Lippershey were opticians of Middleburg.

The story concerning Lippershey runs that he had fitted a lens to a spectacle frame, and was polishing it with a cloth to get it clean. To see how far he had proceeded in this direction he held it up to the window, looking through it. Possibly he had done this often before, but never had he apparently held it at quite the same angle. As now held, he saw through it the steeple of a neighbouring church: what was more important, he observed that the weather-cock at the top of the steeple was far bigger than he had ever thought it to be. At once the explanation of this struck the spectacle maker; it was that the lens was acting as a magnifying glass. There happened to be near him a tube of some kind, and it occurred to Lippershey to place the lens from the spectacles into the tube, and then direct this upon the church steeple. He was amazed at the result, for the weather-cock was even bigger than before.'

Here then, says tradition, was the real beginning of the telescope as we know it to-day. On the other hand the story has been discredited, and some historians profess to think that it was a pure invention. We must admit, however, that it certainly rings true, and if we think of other inventions, we shall also remember that many of them began in a purely accidental way, just as that recorded above. As near as possible, the year of Lippershey's experiment would appear to be 1608.

Whatever happened in that year, we can definitely say that in 1609 there were several telescopes in actual use. The Dutch, always an enterprising nation, were not slow to take up the manufacture of an instrument which promised so much. The coming of the telescope was hailed by every astronomer as the greatest help that could come to him, and quickly Holland was exporting telescopes to all parts of the known world. Some came to England, others went to Germany and France, and one at least was found in Venice.

Now comes another story—which is again traditional. It runs that a certain Galileo happened to be in Venice when the first Dutch telescope was brought there. Galileo was already keenly interested in astronomy, and having seen this new aid to the study of the heavens, he went back to Padua, where he was a lecturer, and determined to make one for himself. One account says that Galileo hit upon the idea without having seen or heard of the Dutch telescope at all, but it does seem more feasible that, in one of his visits to Venice, he should have come across this important Dutch invention. At any rate, the telescope that Galileo made consisted of a leaden tube into which he fitted convex and concave lenses.

Galileo was not satisfied with his first attempt, and shortly afterwards he made another telescope, which was a substantial improvement on the first. He took it to the Doge of Venice, who was intensely interested in this new device, and used it himself for the observation of the celestial bodies. To show

his appreciation of the work which Galileo had done, the Doge doubled his salary as lecturer at Padua: further, he told him that the post was assured for life. This was a very important stipulation, because history shows us that the tenure of any office at that period was always too uncertain.

We are able, by means of the records of Galileo's experiments, to note the progress made in the development of the first telescopes. The first one that Galileo used magnified only three diameters, his next had an eight diameter magnification, and subsequently he increased the power of his telescope until it equalled thirty-three diameters. Moreover, Galileo was solely responsible for these remarkable lenses, nor would he allow any other hand to undertake the polishing of them.

The possession of these relatively fine instruments enabled Galileo to do some important work in astronomy; in fact, the study of the heavens became an obsession with him. Galileo was able to trace the hills and valleys of the moon, and to show to the world the spots on the sun, endeavouring to give an explanation of how they were caused. In addition, he proved that Jupiter had satellites, and that they were in rotation round that planet. Furthermore, he announced that he had discovered the phases of Venus, whilst he showed that the sun rotated on its axis. Whilst he confounded some of the beliefs of that period, he was able to confirm others.

Galileo was so much before his time with his remarkable telescope that he unfortunately came into

collision with the Church. It was an unsettling period, and the Pope had to put his foot down upon these strange innovations and pronouncements of Galileo and his friends. So much pressure was brought to bear upon poor Galileo that he had to unsay a good deal of what he had announced; whether he actually recanted in his own mind it is difficult to say.

Amongst many great names in the development of the telescope, and particularly in the world of astronomy, that of Kepler is a particularly outstanding one. He suggested that, as regards the telescope, very much better results would be obtained if two convex lenses were employed. This announcement was made in 1611, only three years after the reputed discovery of the telescope. But many years were to go by before a Jesuit monk, Christopher Scheiner, produced the telescope suggested by Kepler.

Not long afterwards William Gascoigne believed that the telescope could be still further improved, and he produced the first micrometer for use with it. In addition, Gascoigne added telescopic sights to his new instrument. This helped the astronomer very much indeed; not only was he able to do his work more easily, but he attained a much greater degree of precision. Up till this period it was almost impossible to bring into accurate focus an object which was fairly distant from the telescope.

Another name of great moment in the development of the telescope, and also in the furtherance of astronomy, is Huygens. He produced a greatly improved telescope with the almost immediate result

that he was able to add new stars, and particularly new satellites, to the charts of his day. Amongst others, he discovered Titan, the brightest of the satellites dependent upon Saturn.

The telescopes of Huygens and his contemporaries, marked a very great increase in focal lengths, ranging from thirty-five to two hundred and ten feet. There were even some much larger than these, having lengths of quite six hundred feet. But it seems almost certain that these were not really effective instruments; at any rate, there is no important record directly attributable to them. It seems quite likely that they were more ornamental and imposing than useful.

In the year 1722 James Bradley introduced what he called an aerial telescope, in which the usual tube was dispensed with. It had a length of over two hundred and twelve feet, and one of Bradley's achievements was to measure the diameter of Venus. Telescopes now divided into two classes, the reflecting and the refracting. The reflecting telescope was a development of the instruments used by Galileo and Huygens, whilst James Gregory realised that something more could be done with this description of instrument. Although he made plans for its improvement, he was unfortunate, and, like so many of his predecessors, he was unable to carry out the work with his own hands. It is worth noting here that many of the best telescopes were made by the astronomers who wanted to use them: doubtless their knowledge of what was required led them to produce a design which they were able to carry

into being with their own hands. Gregory lacked this skill, nor was he able to employ any of the opticians of that period to accomplish the work.

Later on, however, the reflecting telescope designed by Gregory, in a slightly different form, was produced, and it is only right that his name should be associated with it.

Another outstanding name in the development of the telescope is that of Isaac Newton. He made a special study of the refracting telescope, and he came to the conclusion that it had too many drawbacks; he therefore set to work to improve the reflecting type. By the year 1666 Newton had demonstrated to the astronomers of that period what a great advance was possible in the making and the use of reflecting telescopes. Newton also made a very fine instrument, and presented it to the Royal Society of London in the year 1761; this telescope had a magnifying power of thirty-eight diameters, and was considered a marvellous instrument at that period.

The next important step forward was achieved by James Short, of Edinburgh; he had gone to college with the idea of fitting himself for a clerical career; whilst there he became so interested in astronomy, and particularly in the manufacture of fine telescopes, that he obtained permission to use his college room for this purpose. So successful were they that Short abandoned the idea of becoming a clergyman, and set up as a maker of telescopes.

The speculæ were made of metal at this period, but Short demonstrated clearly that they could be

made of glass. Newton had made his from an alloy of copper and tin. There was, however, a difficulty with those of glass, and after a time, Short had to come over to Newton's point of view, and he began making the speculæ of a similar alloy. Short's speculæ and lenses were so remarkably well made that many of them are still in existence, and they are as good as the day they were turned out.

The next step was the introduction of the achromatic telescope in 1733. This was discovered by an Essex gentleman, named Moor Hall. Although it was invented in the year mentioned, it does not appear to have been patented then, nor indeed can we trace any telescopes manufactured with these lenses at that period. The achromatic lens, simply explained, is one made up of a combination of glass, resulting in the objects seen from them being free from colour. As it happened, Moor Hall was a fairly well-to-do man, and he had no thought of making his invention a profitable venture. So that the achromatic telescope really came into use some seventeen years later. Dollond had been working on the same problem, and without knowing anything of Moor Hall's experiments, he produced a very similar lens in the year mentioned. The Dollonds were very famous opticians, and Peter, the son of John Dollond, went on to improve considerably, not only the achromatic, but other telescopes. In 1765 Peter Dollond added the triple object-glass.

Still coming down the years, the next name in the development of the telescope, is a very famous one indeed, that of William Herschel. In the 'seventies

of the eighteenth century, Herschel began making telescopes; he wanted to become an astronomer whilst still carrying on his profession of music teacher. It seemed to him that the only way to study the heavens was to obtain the best instrument possible. He arrived at this decision after having used quite small telescopes, and he sent to London to get a quotation for a really fine instrument.

When the quotation arrived, Herschel was astounded at the amount required. To him it seemed an absurd figure, because he argued that the constituent parts of the telescope, that is the raw materials, were comparatively cheap. Feeling that he could not afford so much money, he now took the decision to make his own apparatus, and at once set to work. After teaching all day, and giving his best to that task, he stayed up until the small hours working away polishing lenses, often discarding them because they did not meet his own criticism; he eventually produced a telescope which was fairly satisfactory. The success which met his observations of the heavenly bodies with this telescope spurred him to a fresh effort, and, in 1783 he had produced a very powerful instrument. This had a twenty foot focus, which enabled him to do a good deal of astronomical research.

He was still not satisfied, and in 1789 he produced a really wonderful telescope, having a forty foot focal length, and a four foot aperture. With this remarkable telescope Herschel advanced the cause of astronomy in no uncertain fashion. His greatest achievement was without doubt the discovery of Uranus, thereby

adding another planet to our solar system. This planet had not been recognized by any previous astronomer. Indirectly the discovery of Uranus was the means of Herschel giving up music and becoming an astronomer pure and simple; in fact he was appointed King's astronomer, and went to live near Windsor, where his sister, Caroline, helped him in some really outstanding work. Herschel became very famous for the making of telescopes, as well as the numerous details he added to the knowledge of the heavenly bodies.

With all this progress there was still the point that the manufacture of efficient lenses proved to be a baffling problem. This was particularly true of the achromatic lenses, and the French Academy of Sciences were driven to offer a substantial prize to glass makers who should produce a sufficiently large lens to be really effective with a telescope. Up to that period it was difficult to ensure a perfect lens whose disc exceeded three and a half inches in diameter. It is quite true that much larger ones were produced, but they were never flawless, and for the purposes of the telescope they were relatively valueless.

In connection with the history of the telescope, it is worth noting here that in all essentials the telescope of to-day is practically the same as those made by the Dollonds in the late eighteenth century. Many refinements have been added, of course, whilst the size has grown enormously. But just as the steam locomotive of to-day is the same, in practically all essentials, as that of Stephenson's *Rocket*, so is the

comparison a fair one with the telescope of to-day with those produced by Dollond.

The reflecting telescope is made in very many forms, and its efficiency depends largely upon the concave mirrors which are employed. The two best known types are the Gregorian and the Cassegrain. These are named after their originators. In their general plan there is not a great deal of difference, but in recent years those modelled upon the Cassegrain type have proved more popular. There are some remarkable giant telescopes on the Cassegrain system at Mount Wilson, California, and Melbourne Observatories. A great deal depends upon the speculæ; although to-day the speculæ are successfully made from glass upon which silver has been deposited, there was a great deal of trouble with them when Newton's formula of an alloy of copper and tin was followed; the trouble was to keep them untarnished. In constant use as they were, it was impossible to avoid tarnishing, and the marks could not be removed by any of the usual methods of cleansing; in every case re-figuring was involved. Now this was a particularly delicate process, and needed the attention of a very expert craftsman.

The making of speculæ is a very intricate piece of work; it is necessary to shape and polish them, using the same kind of tools as in lens making. Particularly must care be taken in the careful figuring which is necessary; a slight blunder and the work of hours if not of days, is completely spoiled.

The refracting telescope is made up of a convex objective which is capable of forming the image of a

distant object. It has an eye-piece through which the image is greatly magnified. Both reflecting and refracting telescopes are used in modern observatories.

Much depends upon the mounting of a telescope. When we consider the numerous giant instruments which are found in the up-to-date observatories, it is clear that the mounting arrangements must be well thought out and efficient in action. Sometimes it is arranged that a large platform is made which carries the whole apparatus in a complete circle. On the other hand, it is desirable to have this platform arranged in such a manner that it can be raised and lowered at will. Electric power is now favoured for this work, but there are some ingenious pieces of apparatus which depend upon hydraulic motors for moving the floor. So delicate is the mechanism that the merest touch will set the machinery in motion, and it is possible to arrange for the raising and lowering of the tube of the telescope with the greatest accuracy. It will be understood that where the telescope is used for photographing the heavens, in which a long exposure is needed, there must be no fault in the moving platform or floor. Mercury baths are frequently employed in which the mountings are floated.

With the vast increase in the size of the modern telescope, much more satisfactory results are obtained, and it is merely a question of pounds, shillings and pence, as to how far the development of the telescope can be carried.

CHAPTER XXIV

A WONDERFUL OBSERVATORY

ONE OF the most wonderful observatories in the world is situated on Mount Wilson, which is in the State of California. Not only is it of great interest to those who follow astronomy, but the general public are now becoming regular visitors to see the wonders which Mount Wilson possesses. There are several powerful telescopes, and a museum of astronomical specimens.

The Mount Wilson Observatory is rich in the possession of a 100-inch telescope, which is always known as the Hooker Telescope. There is also a range of astronomical figures in the museum which have been secured through the use of the powerful telescopes installed there.

The Director has recently introduced a system by which the public are allowed to make use of the 60-inch telescope, and many a person who has never seen the celestial bodies save with the naked eye, has had a fairly close up view of the moon, planets, and stars. At the same time the professors of the observatory are able to give illustrated lectures, and these have proved of special interest and value to the teachers and students of the various high-class schools and colleges of Southern California.

Romance has largely entered into the history of this observatory. It began mainly through the efforts of Dr. George Hale, formerly Director of the Yerkes Observatory, who was anxious to gain the most suitable spot possible for using a powerful telescope, particularly to observe the sun. It was desirable to have the best climatic and atmospheric conditions possible, and yet it was essential, from Dr. Hale's point of view, that the observatory should not be too far from a large city, because of the necessity of securing supplies, and also a place where instruments could be ordered, and, if possible, made. Professor W. G. Hussey, of the Lick Observatory, was called in for consultation. His knowledge of suitable positions was invaluable, especially as he had previously made investigation of sites in Arizona and Australia, whilst he had a very good knowledge of practically all the possible sites in California.

It was upon his recommendation that Mount Wilson was chosen for the site of the observatory. Before, however, anything was done, Dr. Hale determined to make astronomical observations there, and these he carried out during the winter of 1903–4, using a 3¼-inch telescope. The results were so good that the Carnegie Institute of Washington granted sufficient funds in April, 1904, to place what was known as the Snow Telescope on Mount Wilson. Within a year, observations were actually begun with this telescope. In addition, small temporary instruments were employed, pending the provision of permanent equipment.

Very fortunately, the trustees of the Carnegie Institution realised the enormous possibilities of the situation of Mount Wilson; they therefore decided to give as much support as possible to the new observatory. In addition, they determined that it should be the major Research Department of the Institution.

Dr. Hale was appointed Director, and was joined by several of the staff of the Yerkes Observatory, and they all gave their Director their enthusiastic support.

The next step was to make plans for the establishment on Mount Wilson, and also in the town of Pasadena.

When the Mount Wilson Observatory was first opened it was intended that observation should be kept only upon the sun. For this reason the original title was the Mount Wilson Solar Observatory, but when the 100-inch reflector was installed in 1918 it was decided that the whole of the celestial bodies should be brought under regular observation; the word solar was, therefore, omitted from the title.

The observatory lies roughly eight miles, as the crow flies, to north-east of Pasadena. The buildings are grouped upon one of the highest peaks of the Sierra Madre range, which rise to an altitude of something over 5,000 feet above the sea level. In spite of this altitude the observatory is readily accessible by a very good road which commences at the foot of the mountain, and rises almost continuously for nine miles. This road was actually

built by the management of the Observatory in order that supplies of all descriptions could be conveyed by motor-car to the summit of the mountain. The road is, however, now owned and operated by a company, which levies a small toll upon all traffic. This company has an hotel adjoining the observatory; indeed, it was due to the Pasadena and Mount Wilson Toll-Road Company that the authorities of the observatory were able to secure so unique a site. The Carnegie Institution were granted a long lease of the land at the summit, and thus the observatory came to be built there.

It would have been a difficult matter to have hit upon a better site than has been chosen, since it is high enough above the valley to miss the haze and fog which frequently envelope the lower ranges.

On the other hand it does not suffer from the severe cold and frequent storms which are found in the highest mountains. Lying between the sea and the desert helps still further to secure Mount Wilson a very equable temperature. How equable the temperature and weather conditions are may be judged when it is stated that for 290 days of the year observations have been possible.

The fact that the observatory is so accessible has enabled a splendid library numbering 10,000 volumes to be assembled at Pasadena, where there are also offices, laboratories and workshops. The astronomers responsible for the work of the observatory live in Pasadena, and they go to the mountain top only when they have need to take observations. These

are possible throughout the whole of the year except when in the winter severe storms are apt to block the road. Full use is made of the Californian summer, when for weeks on end the wind drops and the sky is cloudless. Although so high, Mount Wilson rejoices in plenty of trees and shrubs. These are very useful to the astronomers, since the thick growth protects the mountain from the direct rays of the sun, and by this means diminishes air currents which might prove a distinct drawback to effective observation.

At the outset the Mount Wilson Observatory was planned with three distinct services in view; these were, (1) The measurement of changes in the amount of Solar radiation; (2) Intensive studies of Solar Phenomenon; (3) Investigations of Stars and Nebulæ, for the purpose of throwing light on the problems of Stellar evolution.

To enable these important duties of the astronomer to be effectively undertaken, it was decided that the largest instruments obtainable were to be chosen, and also that the most advanced methods of photography and spectroscopy known, were to be utilized.

It was arranged after the Observatory had been got fairly under way, that the study of solar radiation should be undertaken by the Smithsonian Institution. For some time this work was carried on very successfully by Dr. Abbott, with an independent equipment on Mount Wilson, but more recently stations have been opened in Arizona, Chile, and South Africa and Table Mountain of California.

For more than twenty years now, this splendid programme has been carried forward with enthusiasm by all employed upon it, and there can be no doubt whatever, that the work done at the Mount Wilson Observatory is equal to, if not superior to, that accomplished in any other part of the world.

Much of the success of the Mount Wilson Observatory is due to the fact that lessons learnt with the earlier Yerkes Observatory were carried into the new institution, thus the well equipped physical laboratory for testing and interpreting solar and stellar phenomenon, was started at Pasadena. To this has been added a complete optical and machine shop, where the delicate instruments needed for the Observatory can be made and repaired.

When the Observatory was opened the "Snow" Horizontal Telescope for solar, and the 60-inch reflector for stellar observations were installed. Later on, a 60-foot tower telescope was installed for solar observations. To this was added a 150-foot tower telescope, and then came the Pasadena Solar Laboratory. For stellar and nebular observations a 10-inch photographic reflector was added. Then came the 100-inch Hooker Reflector, and also the 50-foot interferometer.

It says much for the observatory staff, that with the exception of the "Snow" telescope purchased from the Yerkes Observatory, all the large instruments were designed by them. There is a very good and well-equipped engineering department at Pasadena, and here the detailed drawings were made.

The optical parts were finished in the shop devoted to this branch, whilst the machine work, except for some of the largest parts, was accomplished in the instrument shop. A staff varying from 10–20 skilled workmen were employed to accomplish this work.

The instruments in use at the Mount Wilson Observatory are of particular interest not only to the astronomer, but to anyone who has studied, in the slightest degree, the celestial bodies. As already mentioned, the "Snow" telescope was the first of the large instruments to be installed at the Observatory. A Coelostat receives the light of the sun and reflects it to a plane mirror, which in turn throws the beam nearly horizontally upon the concave mirror of 24-inches aperture and 60-feet focal length. For more than twelve years, daily solar photographs were obtained with this magnificent instrument. Within recent years a 30-foot spectrograph-well has been added, whilst the telescope is still used for observations requiring a mirror rather than a lens for the formation of the image.

The tower telescopes are an improvement upon the "Snow" instrument, in that the path of the beam is vertical instead of horizontal, and that the mirrors are placed high above the ground where they are less disturbed by heat waves rising from the earth. In each of the towers the spectrograph is mounted in a well under the tower, the depth of the well being one half the height of the tower. The design is original and has proved convenient and entirely satisfactory.

The smaller tower employs a lens of 60-foot focal length for forming the solar image. It is used daily for direct solar photographs and for spectroheliograms showing the hydrogen and calcium clouds over the surface of the sun, as well as for general spectrographic investigations. The large tower has a lens of 150-feet focal length. The spectrograph is 75-feet in length, giving a high dispersion to the solar spectrum on account of its great height. The 150-foot tower telescope forms a large image of the sun seventeen inches in diameter, which makes it possible to examine carefully even the smallest details appearing on the surface. This famous telescope is regularly used for the determination of the magnetic fields in sun-spots; it is also used for taking measurements of the solar rotation, and for many investigations which need a really powerful instrument.

In the Solar Laboratory at Pasadena there is also a powerful telescope and spectrograph very similar to the equipment of the 150-foot tower. This equipment forms a very valuable supplement to the apparatus at the Observatory.

Another marvellous instrument is the 60-inch reflector. The large disc of glass for the mirror was obtained from France, by Mr. W. E. Hale. The work of grinding was begun by Professor W. G. Ritchley, at the Yerkes Observatory, soon after its dedication in 1897. Unfortunately, however, funds did not permit of its mounting at the Yerkes Observatory, but the misfortune of this Observatory turned out to be a slice of good fortune for that at Mount Wilson. Apart from the more favourable weather conditions

obtainable in California, it was seen that greater use would be made of the apparatus, which was then completed in the Pasadena Shop. The Carnegie Institution came to the aid of the new owners, providing both the mounting and the dome, and observations were begun in 1908. For almost ten years this was the largest telescope in active use.

CHAPTER XXV

THE WONDERFUL INSTRUMENTS OF MOUNT WILSON OBSERVATORY

THE FAMOUS 100-inch telescope was planned after the success in figuring the 60-inch mirror made it clear that a larger instrument was practical. A beginning was made possible by Mr. John D. Hooker in 1906 through a gift of $45,000 for defraying the cost of the mirror itself. The rough disc was cast in France. Upon examination it was feared that the glass would be unsuitable for a mirror because of internal irregularities, but after the failure of the glass founders to cast a perfect disc of sufficient thickness, tests were made to determine the possibility of its use. These proved satisfactory and the work of grinding was begun in 1910. On completion the surface was found to be without flaw or stain.

After six years of work, numerous difficulties and interruptions were overcome, and a paraboloidal figure of great accuracy was produced. The mirror is 101 inches in diameter, about thirteen inches thick, and weighs four and a half tons. When it became apparent that the mirror could be brought to completion, the Carnegie Institution, with the aid of an additional gift to its endowment by Mr. Carnegie, undertook to provide the mounting and

dome for the telescope and to be responsible for its operation. The total cost of the installation of the telescope and dome was about $600,000. The mounting was designed by the Observatory staff and most of the smaller parts were made in the machine shops. The heavy castings, however, were procured from the Fore River Ship Building Corporation at Quincy, Mass., and the large sections of the tube were shipped by steamer around Cape Horn to Los Angeles Harbour.

The tube of the telescope is hung in a rectangular steel yoke which is part of the polar axis. The bearings are relieved by a mercury flotation system with drums over the north and south pedestals. By this method, the telescope, weighing 100 tons, is easily moved in hour angles to follow the course of the stars as they move through the sky from east to west due to the earth's rotation. The telescope is driven by a clock mounted in a room under the south pier. The clock is actuated by a heavy weight and, by means of a worm gear, drives a 17-foot wheel attached to the polar axis. The performance of the driving mechanism is satisfactory even with the coudé combination of mirrors for which the focal length is equivalent to 250 feet.

The optical arrangements of the telescope, like those of the 60-inch reflector, provide for its use with different focal lengths suitable to different kinds of observations. In the Newtonian form there is a single plane mirror to throw the beam from the large concave mirror to the side of the tube; in the Cassegrain form, a convex secondary and a plane

mirror; while in the coudé form, there are a convex mirror of more curvature and a plane mirror which throws the beam down the hollow polar axis of the telescope to a constant-temperature room adjoining the dome on the south. The corresponding focal lengths are 42 feet, 134 feet, and 250 feet.

As the large mirror is subject to distortion with temperature changes, every effort is made to avoid large variations. The 100-foot revolving dome is made double in order to reduce the heating effect of high day-time temperatures, and the mirror itself is surrounded by thick cork-board covers.

In order that the silver coating of the mirror may not become tarnished, it is cleaned and polished with cotton and rouge at frequent intervals. Twice each year the mirror is lowered to the room below and an entirely new coat of silver is applied by chemical deposition from silver nitrate.

Although much larger than any other telescope in use, the 100-inch telescope has met all expectations for its performance. Its resolving and light-gathering power have been so effective in furthering astronomical research that astronomers are looking forward to larger apertures, and designs are now suggested for reflectors up to 300 inches in aperture.

The International Education Board has made a grant to the California Institute of Technology for building a 200-inch reflector to be located in the region of Southern California. The staff of the Mount Wilson Observatory is co-operating in the design and operation of the new telescope.

The 10-inch photographic refractor has a triplet

lens of 45 inches focal length. It is regularly used for the photography of wide fields of stars, for photometric observations and for taking objective-prism spectograms.

Since 1920, measurements of the angular diameters of stars have been made with a 20-foot interferometer attached to the 100-inch reflector. The value of the results obtained justifies the building of a larger instrument for this purpose, which will make possible the measurement of fainter and more distant stars. An interferometer with a 50-foot beam has been designed and the work of construction has been carried out in the Observatory instrument shop. The mounting is entirely independent with its own 36-inch reflecting telescope. The structural steel framework carrying the mirrors is mounted equatorially, and the mirrors, which are 15 inches in diameter, may be separated to a distance of fifty feet.

It is not possible to give here any adequate idea of the results of the numerous researches which have been conceived and developed at the Mount Wilson Observatory in the years 1904–1929. They have involved many new and original methods of attack on problems of the heavenly bodies, as well as old methods which have been pushed to greater limits of precision, or to new fields with more powerful instruments.

In the studies of the sun, important advances have been made to our knowledge of sun-spots and their physical behaviour; the solar atmosphere has been sounded and analysed; general and local magnetic fields have been discovered and measured; the law

of its rotation has been accurately deduced, and a permanent photographic record of the sun's surface, involving over 50,000 plates, has been made available for future study.

Investigations of the moon, planets, stars, clusters, and nebulæ have covered a wide range. With the assistance of instruments of great light-gathering power, researches have been extended to fainter and more distant objects. Long focal length has proved to be of great value in resolving the stars of binary systems, clusters and nebulæ as well as in the study of planetary and lunar detail. Direct photography has revealed the forms of nebulæ and star clusters and has made it possible to study their nature, size and distance. It has also served as an invaluable means of investigating the number, brightness, positions, distribution, colours, and distances of the stars.

Much observing time has been devoted to work with spectrographs, thermocouples, interferometers, and other instruments attached to the great telescopes. In such cases the great mirror serves in the auxiliary capacity of gathering light for the smaller instrument.

Spectrographs are used in connection with the large reflectors for more than one-half of the observing time. They have supplied a large mass of information concerning the constituent elements, temperatures, motions, intrinsic brightness and distances of the stars.

The positions of the components of close double stars and the angular diameters of several of the

larger giant red stars have been measured with the interferometer.

By focusing the rays of a star upon a delicate thermocouple placed in the focus of the 100-inch reflector, the heat radiations from a large number of stars have been measured with great accuracy.

The laboratory in Pasadena has been very successful in imitating and interpreting solar and stellar phenomena. Observations of sources of light in the arc, spark, and furnace, in magnetic fields and vacua, and of electric discharges through fine wires, by analogy, serve to give an idea of the physical conditions prevailing in the sun and stars. Valuable fundamental measurements have also been made in the laboratory.

The greatest single factor in the success of a research institution is the personnel of its staff. The Observatory has been particularly fortunate in this respect. The establishment of the Observatory, the outline of its programme, the design and construction of the large instruments, and the actual research involved in many of the major projects have been largely accomplished through the energy and skill of Dr. George Ellery Hale, the first Director. On account of illness he was made Honorary Director in 1923 and succeeded by Dr. Walter S. Adams, who has been carrying on the administration of the Observatory for several years as Assistant Director. Professor F. H. Seares was made Assistant Director in 1923.

The scientific staff is composed of twenty members who are assisted by a librarian and twelve

computors. With the addition of those associated in the regular work of construction and operation, the total number of persons on the permanent staff of the Observatory is seventy. A number of distinguished astronomers from other observatories throughout the world have been accorded the privileges of the Observatory from time to time and have carried on notable researches in astronomy and allied branches of science.

THE END